REMARKS

Applicants appreciate the Examiner's thorough examination of the subject application and request reconsideration of the subject application based on the foregoing amendments and the following remarks.

Claims 1-22, 55, 63-65 and 67-88 are pending in the subject application.

Claims 23-54 56-62 and 66 were previously canceled.

Claims 1-22, 55 63-65 and 67-88 stand rejected under 35 U.S.C. §103 and/or 35 U.S.C. §112, second paragraph.

Claim 2 was amended to only address the Examiner's non-art based rejections. In addition, claim 4 was amended to avoid possible objections.

The amendments to the claims are supported by the originally filed disclosure.

35 U.S.C. §112, SECOND PARAGRAPH REJECTIONS

Claims 2, 4, and 80-88 stand rejected under 35 U.S.C. §112 on the grounds that there are antecedent basis, indefiniteness and/or vagueness concerns with the identified claims. The Office Action further provides that claim 2 depends from claim 80 and claim 80 depends from claim 2. Thus, the Office Action asserts that the claim dependency for the claims appears unclear. The following addresses the rejections provided by the Examiner.

As provided above, claim 2 was amended to address the non-art concerns specifically identified by the Examiner (*i.e.*, claim 2 was amended to depend from claim 78). Applicants

believe that the areas of rejection have been identified and addressed in the foregoing amendment.

Accordingly, it is respectfully submitted that claims 2, 4, and 80-88 satisfy the requirements of 35 U.S.C. §112 and, as such, are in a condition for allowance.

35 U.S.C. §103 REJECTIONS

Claims 1-13, 15-21, 55 and 63-65 stand rejected under 35 U.S.C. § 103 as being unpatentable over the cited prior art for the reasons provided on pages 2-4 of the above-referenced Office Action. Because claims were amended in the foregoing amendment, the following discussion refers to the language of the amended claim(s). However, only those amended features specifically relied on in the following discussion shall be considered as being made to overcome the prior art reference. The following addresses the specific rejections provided in the above-referenced Office Action.

CLAIMS 1-12, 14, 22, 55, 63 & 67-88

Claims 1-12, 14, 22, 55, 63 and 67-88 stand rejected under 35 U.S.C. §103 as being unpatentable over Peyman [USP 5,487,725; "Peyman `725"] in view of Banko [USP 3,618,594; Banko `594]. Applicants respectfully traverse as discussed below.

Before proceeding with the discussion of the teachings and disclosures of the cited references, Applicants first provide a general background discussion regarding the anatomy of

the eye. As to the eye's anatomy, Applicants attach herewith some excerpted figures. For convenience, figure numbers A-D have been added to the excerpted figures for ease of referring to them in the following discussion. Fig. A was excerpted from "Anatomica, The Complete Home Medical Reference" published by Barnes & Noble, Inc. by arrangement with Global Book Publishing Pty Ltd. (2001, reprinted 2003) and Figs. B-D were excerpted from "Wall Chart of Human Anatomy" published by Barnes & Noble by arrangement with Antographica, LLC (2001), where the 3D Anatomy provided therein was based on the National Library of Medicine's Visible Human Project.

A front view of the eye is shown in Fig. A as it would appear to one looking closely at the face of a person and Fig. B is a side view of the bony orbit with an eye therein. Figs. C and D illustrate the external musculature and vasculature of the eye.

As can be seen from a comparison of Fig. A with Figs. B-D, only a small portion of the eye is actually visible from the front, and the rest of the eye is enclosed and protected. As can be seen from Fig. A, the cornea of the eye is visible and the rest of the eye is not visible as it is covered by a thin membrane, the conjunctiva or bulba conjunctiva that lies over and covers the front of the eye and which also forms the lining of the eyelid.

As previously indicated by Applicant, the conjunctiva, and as seen from the excerpted figures as well as the text included therewith, the outer layer of the of the eye (the sclera) is covered by a thin member, the conjunctiva. Thus, this thin membrane called the conjunctiva is a separate layer that is loosely connected to the globe but does not form a portion of the wall of the

globe comprising the eye. Also, piercing of the conjunctiva establishes an opening between the exterior surface of the conjunctiva and the exterior surface of the wall of the eye or sclera.

Applicants claim, claim 1, a method for providing access within an eye during an ocular surgical procedure. Such a method includes providing an entry alignment device that is configured so as to provide an entry aperture in each of the conjunctiva and sclera of the eye and maintaining the entry aperture in each of the conjunctiva and sclera aligned during the surgical procedure and inserting the entry alignment device into the eye so as to form the entry apertures, where said inserting is accomplished without pulling back of the conjunctiva. Such a method further includes providing a surgical instrument having an operable end for insertion through the entry aperture in each of the conjunctiva and sclera, a portion of the operable end having a cross-sectional diameter not greater than 25 gauge; and inserting the surgical instrument through the entry apertures into the eye.

The Office Action indicates that neither Peyman `725 nor Banko `594 disclosea or describes that the conjunctiva needs to be pulled back to practice the method and invention described in these patents. As indicated previously by Applicants, one skilled in the art would have readily recognized that the cited references do not fully describe the surgical process being implemented in the patent and that certain language and thus certain portions of the surgical procedure required to be performed to carry out the technique/procedure described in these patents was missing. Applicants also have indicated, that the portions of the technique which

were missing also could be concluded or inferred from the disclosures included in the cited art and based on the structure of the eye.

In this regard, Applicants have attached herewith a copy of Chapter 129 of the second edition of "Retina" and a copy of Chapter 127 of the third edition of "Retina." These Chapters are both entitled "Principles and techniques of vitreous surgery." The third edition is provided essentially to show that the procedure described below in regards to the second edition was not changed in the third edition, although it does included some figures as described hereinafter that show features that are discussed in the second edition.

The second edition of Retina at page 2066 thereof provides the following as to conjunctival incisions.

> Because vitrectomy for most vitrroretinal surgery requires a three-port approach, two conjunctival incisions are required. The temporal incision for the infusion cannula and primary active tools should be 60 degrees in extent and, centered at the lateral rectus, and 2mm from the limbus. Limbal incisions cause bleeding under the surgical contact lens and result in a postoperative ridge, making the fitting of a soft contact lens difficult. A superonasal incision, 2 mm from the limbus and 30 degrees in extent, is used for the endoilluminator and secondary active instruments exchanged from the superotemproal incision.

The second edition of Retina at pages 2066-2067, which follows the discussion regarding the conjunctival incisions, provides the following discussion as to sclerotomies. See also Fig. 129-7 on page 2068.

> An assortment of same diameter (20 gauge. 0.89 mm, 0.033 inch) tools have become a de facto standard and is strongly recommended. All current cannula systems are larger, leak without a plug, and prohibit passage of some essential, axially asymmetric tools.
>
> The wounds should be linear, 1.4 mm long, and parallel to the limbus. A lancet-tipped (symmetric) blade controls the size and position better than asymmetric blades for the sclerotomies. ... A 1.44 mm linear incision rounds out to the 0.89 mm round hole, which should be the size of the blade shank. ... The infusion cannula incision should be made first just below the 3 or 9 O'clock position inferotemporally with a 20-gauge lancet blade passed toward the center of the eye but just deep enough to ensure that the widest portion of the blade and first round section is past the nonpigmented cilliary epithelium. It should be made 4 mm from the posterior to the limbus in adult eyes or 3 mm if the lens has been removed in a prior operation or if a lensectomy is to be performed. The sclerotomy can then be grasped with a 0.1 mm forceps with an angulated end to fixate the eye while the infusion cannula retention suture is being passed. The sutures passes should be parallel to the limbus, short, deep and spaced to accommodate the base plane of the infusion cannula.
>
> The second sclerotomy should be made superonasally just above the 180-degree line, 3 to 4 mm from the limbus, and parallel to the limbus. The endoilluminator tool and associated subsystems should be passed through this opening to stabilize the eye while making a third sclerotomy superotemporally. Scleral plugs are not required or useful at this time.

> The third incision should be just above the 180-degree line, parallel to the limbus, 20 gauge and 3 to 4 mm from the limbus. More anterior or differently located incisions are required in cases of congenital or pathologic abnormalities of the pars planar region or in smaller eyes.

After a discussion of various treatment procedures, the second edition of Retina provides at page 2085 the following as to the suturing of sclerotomies:

> Monofilament 8-0 nylon sutures offer the best compromise between tensile strength and leakage caused by larger-needle diameters. ... A running shoelace suture with three bits for a typical 1.4 mm 20-gauge sclerotomy is fast and easy and offers tight would closure (Fig. 129-37).

After the discussion regarding suturing of sclerotomies, the second edition of Retina at page 2085 provides the following as to the closure of the conjunctiva.

> Running 6-0 plain gut sutures for the 2 mm limbus based flap closure eliminate postoperative conjunctival foreshortening and redundancy. Suturing of Tenon's to the muscle insertion causes ptosis, limitation of ocular motility, and inadvertent conjunctival incisions during re-operation(Fig. 129-38).

In sum, the second edition of Retina describes a process where various incisions are first made in the conjunctiva for the infusion cannula and primary active tools and for the endoilluminator and secondary active instruments and them incisions are made in the sclera so that the infusion cannula, primary active tools, the endoilluminator and secondary active instruments can be inserted through the sclera into the vitreous. Also, Retina describes suturing

of all the incisions in the sclera first and then closing the conjunctival opening or incisions by suturing. To make such incisions in the sclera and to suture the scleral incisions, the conjunctiva is opened up to allow the surgeon to access to the sclera. One also can see from Figs. 129-34, 129-37 and 129-38 that the conjunctiva is pulled back to expose the sclera to give the surgeon the access required to perform a given technique. It also should be recognized that the third edition of Retina includes Fig. 127-10 which shows conjunctival limbus flaps.

It should be noted that Chapter 127 in the third edition of Retina includes Figure 127-45 that includes algorithms for common vitreoretinal disease states. This figure extends over a number of pages, but an algorithm on page 2138 is of particular note; the algorithm entitled "Close Non-Infusion Cannula Sclerotomies (*i.e.*, incisions in the sclera). The illustrated algorithm shows that the conjunctiva is to be closed after all of the sclerotomies are closed (*i.e.*, sutured closed). This is consistent with the discussion in the second edition which also described closing the infusion cannula sclerotomy last and then closing the conjunctiva.

Also, and comparing Figs. A-D to the figures 5-6 and 10-11 in Peyman `725 reveals that the eye shown in these figures in which the instrument is to be inserted does not show the presence of the conjunctiva extending over the sclera or closing off access to the eye such as that shown in Fig. A. This is not be surprising as the description of the eye in col. 8, lines 40-45 of Peyman `725 does not indicate that the conjunctiva is part of the structure being shown. A similar comment can be made regarding Fig. 1 of Banko `594.

Peyman `725 also provides that a sclerotomy incision is made and that an instrument would be inserted through the incision. Peyman `725 further provides that given the small size of the cutting instrument, the incision might be small enough to be self-sealing or require a single small suture. In any event, and as described in Retina, the technique known in the art at the time of Peyman `725 was to make incisions in the conjunctiva and to pull back the conjunctiva so as to thereby expose the sclera so the surgeon could make an incision in the sclera and to later seal the scleral incision by suturing before closing the incisions in the conjunctiva.

As to Banko `594, and as previously provided by Applicants, the technique described in Banko `594 and the device, in particular the cutting blade or instrument make clear that a necessary element of the methodology described in Banko `594, and thus a design feature necessarily embodied by the device disclosed in Banko `594 is that the conjunctiva is first pulled back to expose the sclera before the device is inserted through the wall of the eye.

Banko `594 describes that once the supporting means 50 is inserted into and through the wall of the eye (which is not inclusive of the conjunctiva), two mattress sutures 52 may be conveniently tightened so as to prevent any of the vitreous material within the eye from flowing out. It also is provided that such tightening of the mattress sutures establishes sealing engagement between the supporting means 50 and the wall 25 of the eye. See Banko `594, col. 6, lines 16-20, col. 7, lines 9-13. Banko `594 further describes that when removing the supporting means, an additional pair of mattress sutures are to be gradually tightened as the

supporting means is gradually removed from the wall to close-up the opening 27 in the wall 25 of the eye.

Thus, the sclerotomy formed by the device in Banko `594 is not self-sealing as sutures are being used to seal the opening or sclerotomy. This is not surprising as the blade or piercing end shown in Figures 6-7 and described in Banko `594, as well as that more specific information disclosed and shown in Banko `425, is arranged so as to form an opening that would not be self-sealing.

As indicated in the discussion above regarding Retina, and is known to those skilled in the art, a sclerotomy is an incision that is made in the sclera/ wall of the posterior segment of the eye, more preferably in the pars plana. As also indicated in the discussion in Retina, an incision is first made in the conjunctiva to expose the area of the sclera where such an incision(s) is to be made and the opening in the conjunctiva is closed by suturing after the suturing the incision in the sclera to close such a scleral incision .

Thus, the technique described for the device in Banko `594 must inherently include making an incision in the conjunctiva to expose the sclera prior to making an incision in the sclera/wall of the eye and closing the opening in the conjunctiva after the incision in the sclera/wall of the eye is sutured closed.

Thus, both references inherently teach and disclose that the technique being disclosed in each patent also inherently includes making incisions in the conjunctiva necessary to allow the surgeon to expose the sclera and so that incisions can be made in the sclera. Such exposing, as is

described in the subject application as well as being known to those in the art includes pulling back or moving the cut portions of the conjunctiva out of the way to expose the sclera such as the flaps shown in Retina, third edition.

It also should be noted that the teachings in Retina provide that conventional cannula systems are larger than the 20 gauge instruments. As is noted in the subject application as well as based on the teachings in Retina, such sized instruments would require making incisions in the sclera that would needed to be sutured to close the incision. Consequently when all the prior art is considered as a whole, the prior art teaches way from the use of an entry alignment device for forming an opening in each of the conjunctiva and sclera as the opening formed in the sclera as taught by the prior art would have to be closed by sutures which necessarily means that the conjunctiva would have to be cut (incisions made therein) and manipulated so as to expose the sclera to make the incisions in the sclera.

Applicants respectfully submit that the foregoing remarks distinguishing claim 1 from the cited combination of references also at least applies to distinguish the methodologies of each of claims 55 and 78.

It is respectfully submitted that claims 1-12, 14, 22, 55, 63 and 67-88 are patentable over the cited reference(s) for the foregoing reasons.

CLAIMS 13, 15-21, 64 & 65

Claims 13, 15-21, 64 and 65 stand rejected as being unpatentable over Peyman [USP 5,487,725; "Peyman `725"] in view of Banko [USP 3,618,594; Banko `594] and further in view of Saperstein et al. [USP 5,919,158; "Saperstein] for the reasons provided on pages 3-4 of the above referenced Office Action. Applicants respectfully traverse.

Claims 13, 15-24, 64 and 65 depend respectively from one of claims 1 or 55. As indicated above, Peyman `725 and Banko `594 alone or in combination do not disclose, teach nor suggest the methods as set forth in either of claims 1 or 55. Moreover, there is no teaching, suggestion nor motivation offered in either of the cited references to modify the methodology disclosed in the primary reference, Peyman `725, so as to yield either of the methodologies claimed by Applicants. As such, each of claims 13, 15-21, 64 and 65 are considered to be in allowable form at least because of their dependency from an independent claim that is considered to be allowable. As to the tertiary reference, Saperstein, Applicants make the following observations.

Saperstein is used in the grounds for the rejection for the limited purpose of teaching the use of a light source to illuminate an area. Saperstein, however, also describes the known technique of inserting surgical instruments/ cannulas/ light probe through a sclerotomy (*i.e.*, sclerotomy incision) in the eye. Thus, Saperstein does not disclose, teach or suggest the transconjunctival methodology claimed by Applicants. Moreover, there can be no teaching, suggestion or motivation offered in the tertiary cited reference to modify the methodology

disclosed in the primary reference, Peyman '725, so as to yield either of the methodologies claimed by Applicants.

It is respectfully submitted that claims 13, 15-24, 64 and 65 are patentable over the cited reference(s) for the foregoing reasons.

The following additional remarks shall apply to each of the above.

As provided in the foregoing remarks, the cited references do not teach or suggest the features of the provided entry alignment device claimed by Applicant. Further, the cited references do not teach or suggest the combination of steps of the method claimed by Applicants. In addition, there is no suggestion anywhere in these references that such a combination would be reasonably successful.

The Federal Circuit has indicated in connection with 35 U.S.C. §102 that in deciding the issue of anticipation, the trier of fact must identify the elements of the claims, determine their meaning in light of the specification and prosecution history, and identify *corresponding elements* disclosed in the allegedly anticipating reference (emphasis added, citations in support omitted). *Lindemann Maschinenfabrik GMBM v. American Hoist and Derrick Company et al.*, 730 F. 2d 1452, 221 USPQ 481,485 (Fed. Cir. 1984). Notwithstanding that the instant rejection is under 35 U.S.C. §103, in the present case the Examiner has not shown that the devices and method steps in any of the cited references corresponds, as that term is used above by the Federal

Circuit, in any fashion to the provided entry alignment devices and methodology in their entire claimed form as set forth in any of claims 1, 13 and 55 of the present invention.

As provided in MPEP 2143.01, obviousness can only be established by combining or modifying the teachings of the prior art to produce the claimed invention where there is some teaching, suggestion, or motivation to do so found either in the references themselves or in the knowledge generally available to one of ordinary skill in the art. *In re Fine*, 837 F. 2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988); *In re Jones*, 958 F. 2d 347, 21 USPQ2d 1941 (Fed. Cir. 1992). As provided above, the references cited, alone or in combination, include no such teaching, suggestion or motivation.

It is respectfully submitted that for the foregoing reasons, claims 1-12, 14, 22, 55, 63 and 67-88 are patentable over the cited reference(s) and satisfy the requirements of 35 U.S.C. §103. As such, these claims, including the claims dependent therefrom are allowable.

It is respectfully submitted that the subject application is in a condition for allowance. Early and favorable action is requested.

Applicants believe that additional fees are not required for consideration of the within Response. However, if for any reason a fee is required, a fee paid is inadequate or credit is owed

for any excess fee paid, the Commissioner is hereby authorized and requested to charge Deposit

Account No. **04-1105**.

Respectfully submitted,
Edwards & Angell, LLP

Date: December 2, 2005

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CHAPTER

129

Principles and techniques of vitreous surgery

Steve Charles

Vitreoretinal surgery is a complex blend of the most difficult high technology microsurgery applied to a complex pathobiologic system. This relatively new and rapidly growing field requires continued research and training and an honest assessment of one's surgical skills, knowledge, and experience. The surgical team must be well trained, efficient, and technologically competent; the complex equipment must be constantly maintained and updated as the technology progresses.

To help deal with the complexity of vitreoretinal surgery, researchers recently proposed a new approach utilizing a surgical algorithm made up of scenarios. The surgical scenarios are similarly composed of smaller elements referred to as tools, associated analog parameters (pressure, power, temperature, etc.), and digital interconnects (fluid-gas exchange, air-silicone exchange, etc.). Scenarios are common to the surgical approach to different disease status that share common pathoanatomic configurations. Each algorithm contains decision nodes with several alternative scenarios. The decision process requires clinical research information, knowledge of physical principles, individual patient factors, and intuition. This chapter will begin with a description of relevant general pathoanatomy, with specific information left to other chapters on specific disease states. Understanding the mechanics of the tools used will allow discussion of the details of how to perform each scenario. The chapter concludes with a suggested algorithm for each common disease state, with specific management details again left to other authors.

VITREORETINAL SURGICAL ANATOMY

The vitreous must be understood as a three-dimensional matrix of collagen fibers and hyaluronic acid gel. In the normal state, the outer surface of the vitreous is in contact with the retina, pars plana, and ciliary body in a roughly spherical shape with a facet anteriorly for the lens. Disease-induced cellular infiltration against a background of age-related changes causes contraction of the collagen matrix, with a majority of relevant changes occurring along the continuous outer surface. The anterior hyaloid face (AHF) is continuous with the posterior hyaloid face (PHF) and, for the most part, is a nonfenestrated surface.

Abnormal glial, retinal pigment epithelial (RPE) fibroblastic, and other cells migrate along the front and back surfaces of the retina and vitreous. Many cells have coated pits containing fibronectin, allowing them to attach to and contract the collagen matrix.*

A detailed understanding of the abnormal vitreoretinal interface and its derivative geometry is requisite to undertaking vitreoretinal surgery. The task involves visualization of vitreous and periretinal membranes to be removed and a systemic search for membranes based on observed retinal topology. In general, membranes are white and matte finish, whereas the retina has a surface luster and appears pale yellow. If a complete posterior vitreous detachment has not occurred, there is usually continuity between areas of epiretinal membrane (ERM) and adjacent detached PHF. Because the retina typically does not contract or contain intraretinal proliferation, changes in contour occur because of perpendicular vitreous traction (funnel, plateau, or ridgelike elevations) or tangential periretinal membrane traction (starfolds).

Retinal breaks result in a relative decrease or loss of the normal transretinal pressure gradient. Transhole flow is related to intraocular pressure, health of the RPE pump, viscosity of the fluid, and the size of the retinal break.[15,16]

MECHANICS OF VITREORETINAL SURGERY

An understanding of the physical principles of surgical tools enhances the capabilities of the vitreoretinal surgeon. Discussion of the forces available for cutting and thermal effects follows. Cutting may simply be defined as the separation of a substance into two parts.

*References 9, 11–13, 45–48, 55, 56, 58, 60, 61, 77, 81.

Elongation

Use of elongation causes collagen fibers to fail. Damage to attached structures is a function of the number of fibers and the strength of the attachment and substrate. Membrane peeling or stripping requires force perpendicular to the retina and causes failure of the attachment at the vitreoretinal interface by elongation.

Compression

Compression causes the material being cut to fail via high pressure per unit area between the cutting edge and a backstop. Suction applied to a port without a cutter or ultrasound creates compression around the edge of the port and elongation of the tissue in the center of the port. This principle is used in so-called infusion (irrigation) aspiration (suction) systems.

Shear (double)

Shear occurs when force is applied along two opposing planes. The vitrectomy cutters and scissors use shear to cut tissue. Inclusive shears such as a vitreous cutter prevent the extrusion force that occurs as typical exclusive shears (scissors) close, pushing the tissue away from the blades.

Fatigue failure

Fatigue failure occurs when repetitive motion, elongation, and compression weaken tissue structure and cause failure. Ultrasonic sonification (fragmentation, emulsification) is an example of this mode.

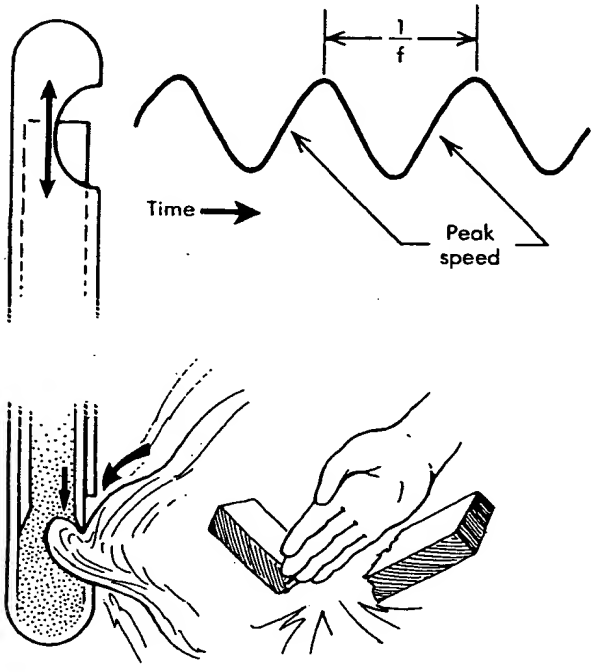


Fig. 129–1. High-frequency cutting reduces vitreous fiber travel before cutting, and high cutter velocity uses tissue inertia for clearer cutting and less traction.

VITREOUS CUTTER CONSIDERATIONS

All current vitreous cutters involve suction and inclusive shearing. Ideal tissue cutting is defined as that producing zero displacement of the tissue, zero thermal damage, and small kerf (removed tissue). The lowest suction force that will cause the material to be sheared is the safest (Fig. 129–1). If the inner cutter has high velocity, the port acts as if it is open most of the time, resulting in nonpulsatile fluid flow and less vitreoretinal traction (Fig. 129–2). High-speed travel of the shear uses the inertia of the tissue to change apparent mass and facilitate cutting (Fig. 129–3). In summary, low-suction, high-cutting velocity and frequency, and large ports provide the safest cutting. Maintaining sharpness of the cutter is required to prevent the tissue tearing associated with a misaligned shear (Fig. 129–4).

CONTROL SYSTEMS

All analog parameters using surgical force such as suction, laser power, radiofrequency (RF) power, shearing

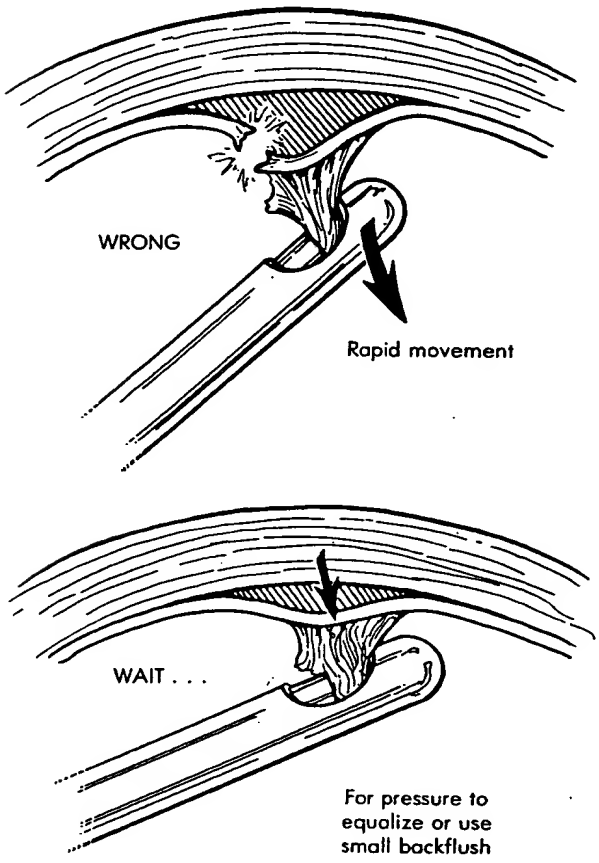


Fig. 129–2. Rapid withdrawal of a cutter with entrapped tissue can tear the retina or iris.

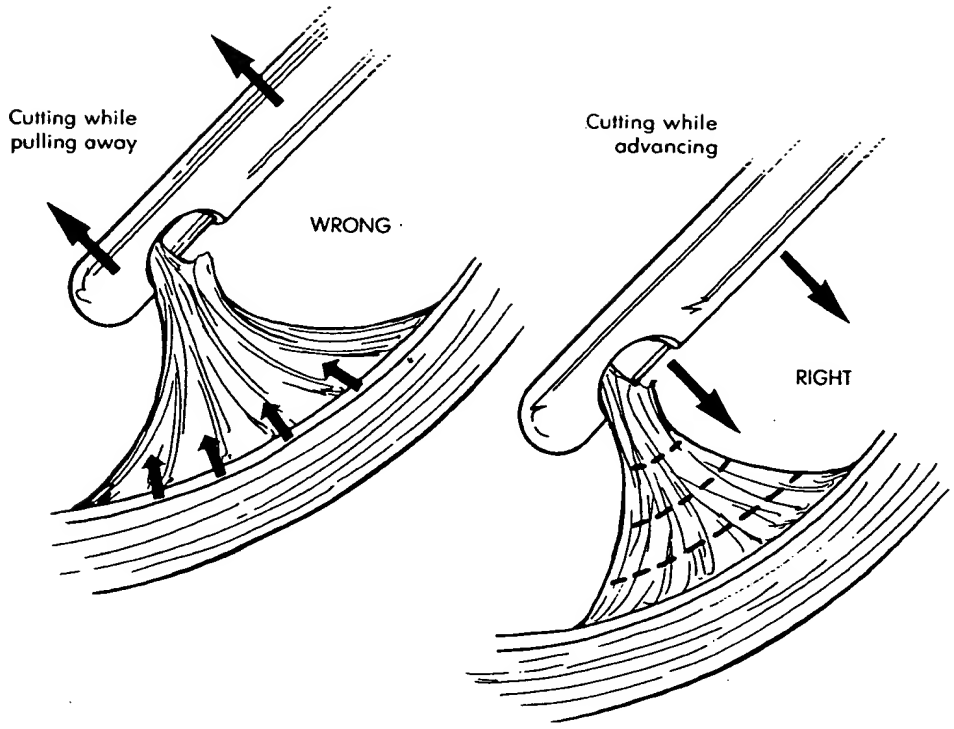


Fig. 129–3. Movement of the cutter toward the tissue to be cut avoids addition of the traction force from movement to suction-induced force.

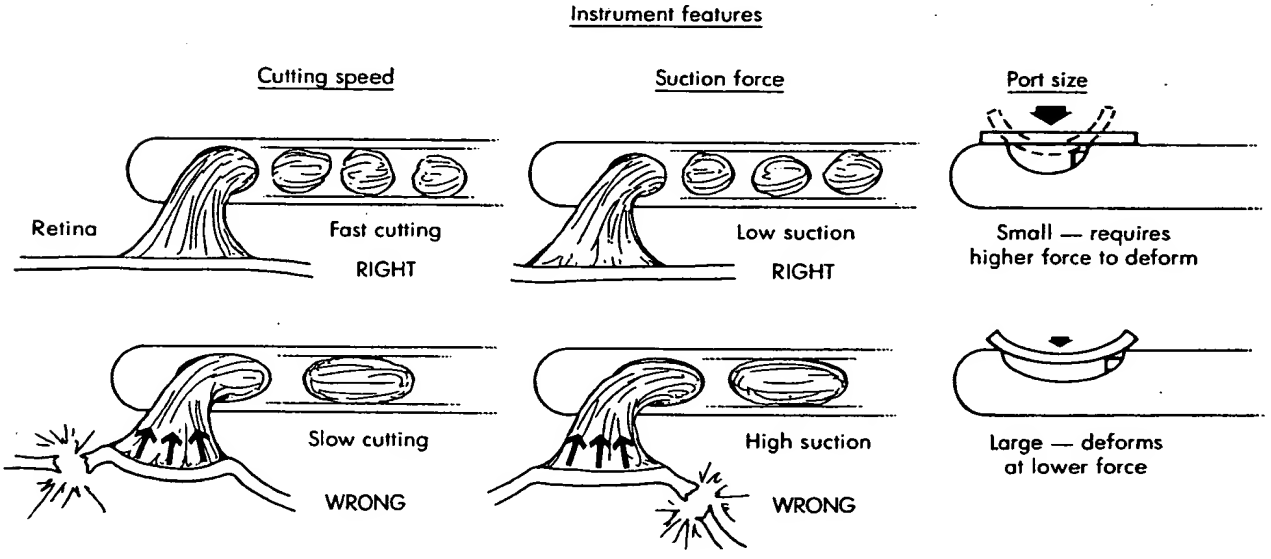


Fig. 129–4. Suction force should be controlled with a proportional foot pedal so as to use minimal suction force at all times and reduce undue traction.

rate, and injector rate should be controlled by proportional depression of the surgeon's foot (linear control). Switching of valves, pumps, electronic devices, and lasers should ideally be controlled by a single integrated system, with functions controlled by the surgeon rather than the nurse or technician.

MICROSCOPE REQUIREMENTS

A stereo operating microscope with magnification up to ×30 or ×40 with coaxial illumination is required. The device should have high transmissivity to facilitate television imaging for the operating room team and for recording. Ideally any television system should be high

definition (HDTV) and stereoscopic. At least one assistant should share the surgeon's view, preferably with stereopsis, but most current systems also ignore this problem.

Microscope control can be by foot switch, voice control, or surgeon's head tracking. Voice control is slower, surgeon specific, and somewhat demanding for the surgeon. Power zoom, focus, and XY positioning are required. Head tracking offers the most natural interface.

Physical stability of the microscope and patient's head is required to preserve the dimensional stability of the surgical view for microsurgery. Current ceiling-mounted microscopes are better than floor-mounted microscopes for this reason. Operating tables are significantly unstable when contacted by the other members of the operating room team. A stable wrist rest is required for the surgeon, and creating a moat around the patient's head traps effluent fluids and inadvertently dropped surgical tools. The goal is to provide a stable dimensional relationship among the microscope, the patient's head, and the floor systems.[24,70]

Preferably, all power sources for surgical tools should be combined into one physical system for better access to the surgical field. New systems will have unified control combining all surgical functions in a single sterile device near the surgical field.

HANDPIECE CONSIDERATIONS

All surgical tools should be as light as possible and held in the surgeon's fingertips. They should be contoured rather than cylindrical to reduce the force required to prevent dropping (Fig. 129–5). They should be no longer than 35 mm. Shorter handles reduce the torque produced by the weight and also reduce friction from the cables, fibers, and tubing used to connect surgical tools to their power modules. Minimizing forces required to hold tools increases the surgeon's proprioceptive sense (Weber-Fechner) and decreases fatigue and tremor.

SCENARIOS

Conjunctival incisions

Because vitrectomy for most vitreoretinal surgery requires a three-port approach, two conjunctival incisions are required. The temporal incision for the infusion cannula and primary active tools should be 60 degrees in extent, centered at the lateral rectus, and 2 mm from the limbus. Limbal incisions cause bleeding under the surgical contact lens and result in a postoperative ridge, making the fitting of a soft contact lens difficult. A superonasal incision, 2 mm from the limbus and 30 degrees in extent, is used for the endoilluminator and secondary active instruments exchanged from the superotemporal incision.

Traction sutures are unnecessary and disadvantageous for vitrectomy. They are required only if scleral buckling is planned. In the case of anticipated scleral buckling, the muscles should be trapped with chamfered hole, fenestrated, short-handled muscle hook and 2-0 silk (not 4-0) suture used to facilitate the assistant's grip and reduce trauma to the muscles (Fig. 129–6).

Sclerotomies

An assortment of same-diameter (20-gauge, 0.89-mm, 0.033-inch) tools has become a de facto standard and is strongly recommended. All current cannula systems are larger, leak without a plug, and prohibit passage of some essential, axially asymmetric tools.[69]

The wounds should be linear, 1.4 mm long, and parallel to the limbus. A lancet-tipped (symmetric) blade controls size and position better than asymmetric blades for the sclerotomies. Disposable blades or extremely hard materials are required to maintain an extremely sharp tip for penetration of the choroid and nonpigmented ciliary epithelium. Incisions parallel to the limbus prevent inadvertent anteroposterior enlargement of the sclerotomy. A 1.4-mm linear incision rounds out to the 0.89-mm round hole, which should be the size of the blade shank. No plugs, stilettos, 20-gauge needles, transilluminators, or the like are required. The infusion cannula incision should be made first just below the 3 or 9 o'clock position inferotemporally with a 20-gauge lancet blade passed toward the center of the eye but just deep enough to ensure that the widest portion of the blade and first round section is past the nonpigmented ciliary epithelium. It should be made 4 mm posterior to the limbus in adult eyes or 3 mm if the lens has been removed in a prior operation or if a lensectomy is to be performed. The sclerotomy can then be grasped with a 0.1-mm forceps with an angulated end to fixate the eye while the infusion cannula retention suture is passed. The suture passes should be parallel to the limbus, short, deep, and spaced to accommodate the base plane of the infusion cannula. The cannula is twisted into position in an oscillatory fashion to ensure passage through the ciliary epithelium, and the suture is tied down. The cannula tip is then inspected with the operating microscope magnification if the lens is absent or is to be removed (Fig. 129–7). If the lens is to be retained, indirect ophthalmoscope magnification must be used to inspect the tip to prevent inadvertent infusion under the choroid or ciliary epithelium. If tissue is seen over the cannula, it is incised with a 20-gauge lancet blade from the nasal sclerotomy site if the lens has been removed or is to be removed (Figs. 129–8 and 129–9). If the eye is to remain phakic, the MVR blade is used to incise the tissue over the cannula from the superotemporal approach. If the infusion is anticipated to not be seen because of anterior opacities, a 20-gauge, 30-degree bent infusion cannula should be passed deeply into the eye and used for infu-

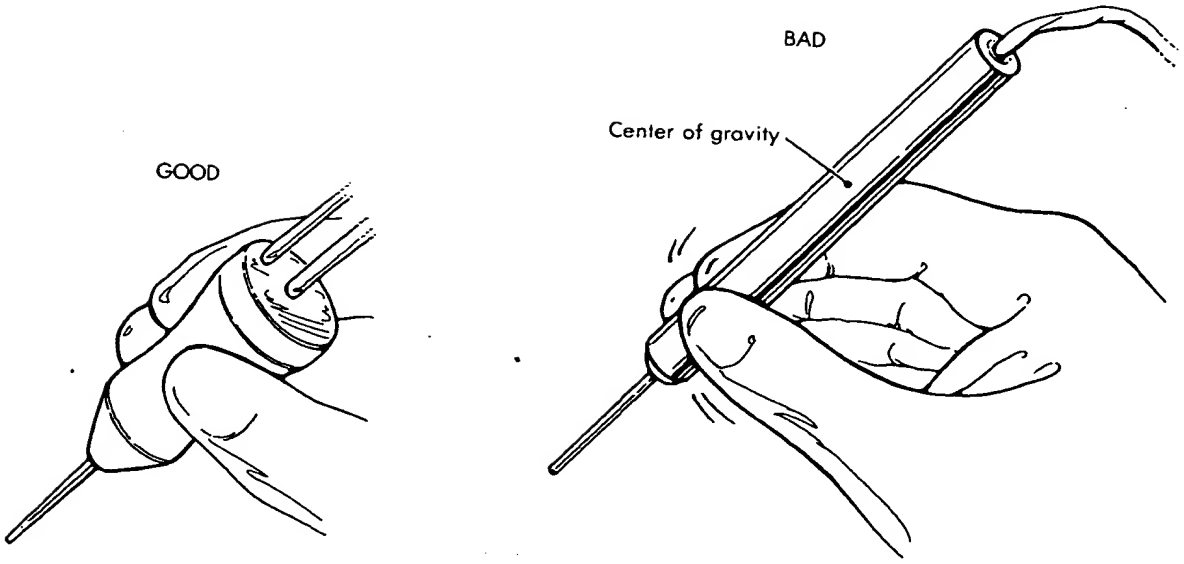


Fig. 129–5. The handpiece should be light, held at its center of gravity, and contoured to reduce holding force and increase proprioceptive sensitivity.

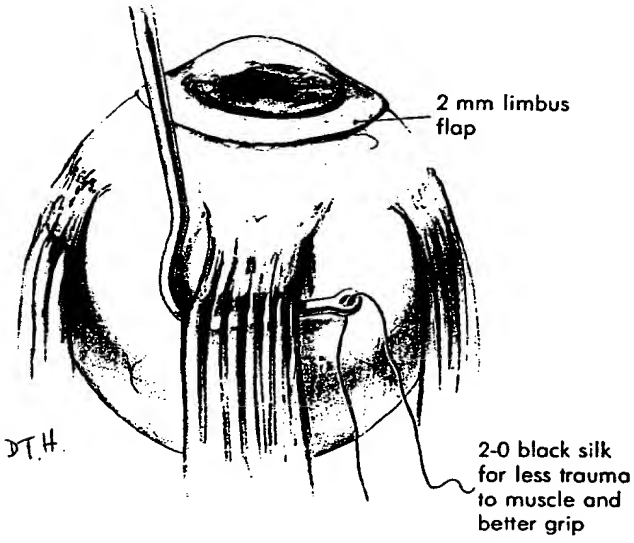


Fig. 129–6. Fenestrated muscle hooks permit safe retromuscle traction suture placement.

sion until visualization of the pars plana is possible. At that time, a standard sew-on infusion cannula can be placed in the usual fashion.

The second sclerotomy should be made superonasally just above the 180-degree line, 3 to 4 mm from the limbus, and parallel to the limbus. The endoilluminator tool and associated subsystems should be passed through this opening to stabilize the eye while making a third sclerotomy superotemporally. Scleral plugs are not required or useful at this time.

The third incision should be just above the 180-degree line, parallel to the limbus, 20 gauge and 3 to 4 mm from the limbus. More anterior or differently located incisions are required in cases of congenital or pathologic abnormalities of the pars plana region or in smaller eyes.

Vitreous removal

Previous algorithms have stressed removal of axial opacities (core vitrectomy), followed by truncation of the posterior hyaloid face. Cutting technology has improved to the point that one algorithm no longer suffices; therefore, each algorithm should be selected according to the specific pathoanatomy of the case. If the AHF is semiopaque, opaque, or taut, it should be removed first. If it is clear and the lens is to be left in place, it should be retained unless there is an element of anterior loop trac-

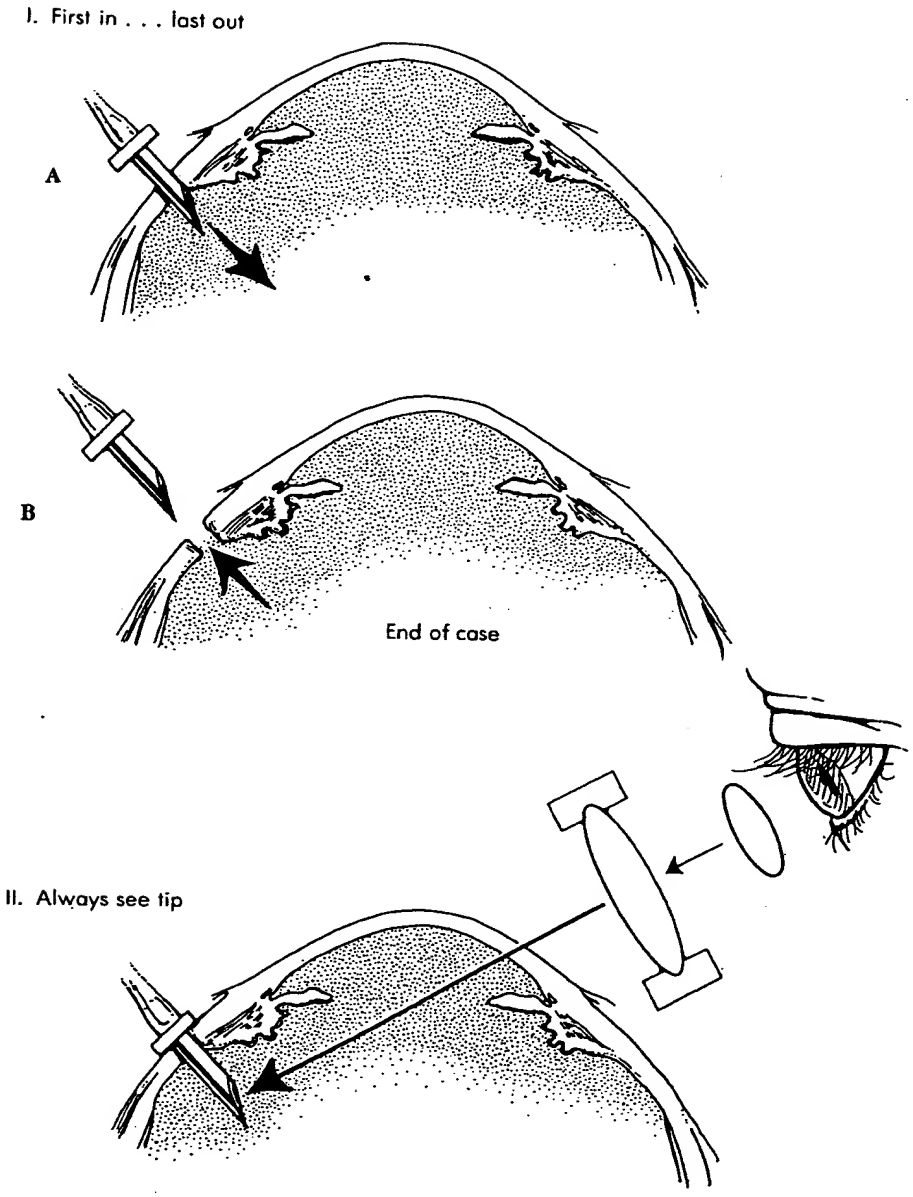


Fig. 129–7. I. A, A 20-gauge lancet blade is used to make a 1.0-mm sclerotomy parallel to the limbus. The infusion cannula is placed in the first sclerotomy made. **I. B,** The infusion cannula site is the last to be closed. **II.** The infusion cannula must be visualized with magnification before infusion fluid is allowed to flow into the eye. **III.** Infusion is allowed to flow during the entire case without interruption.

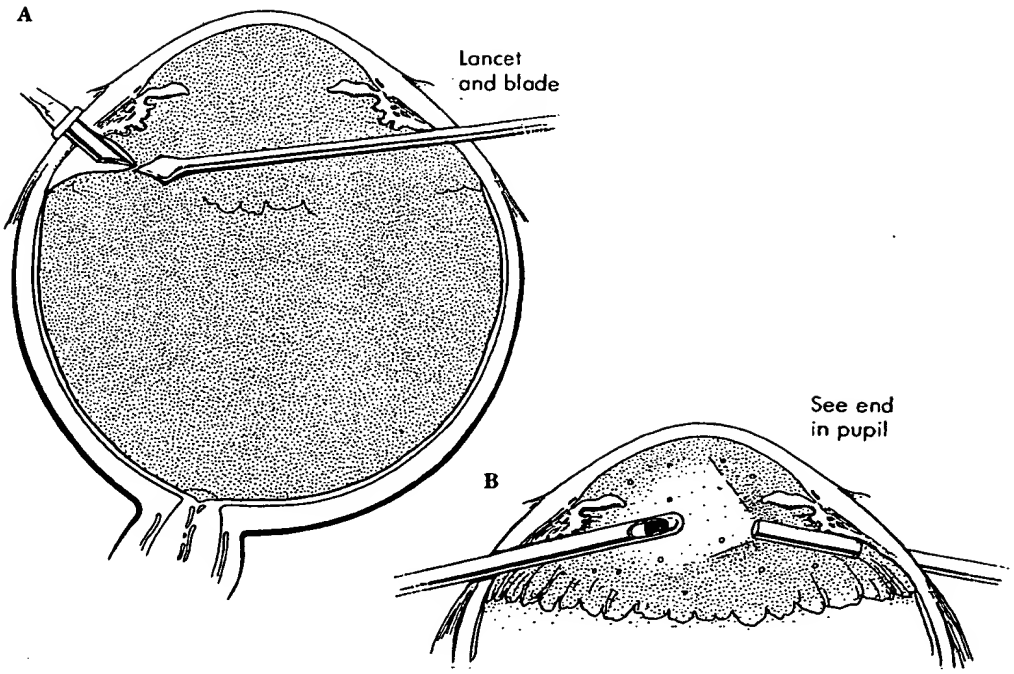


Fig. 129–8. A, Tissue over the cannula can be incised with a lancet blade if the lens is absent or to be removed. Otherwise the cannula must be removed, prefirming with a 20-gauge needle and replaced. **B,** Hyphema, dense cataract, or pupillary membrane must be managed by infusion with a handheld 20-gauge long cannula until the pars plana is visualized, permitting sew-on cannula placement.

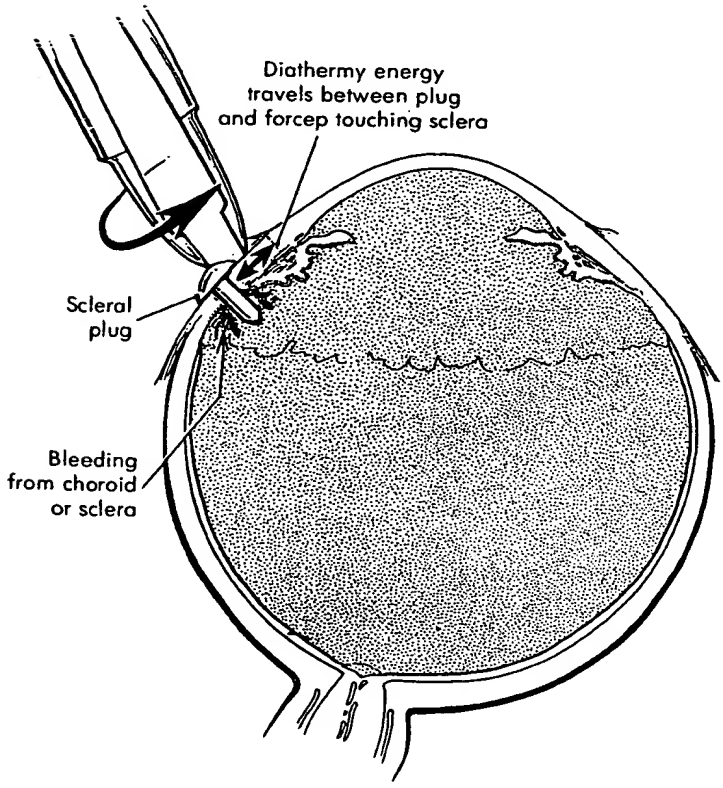


Fig. 129–9. Bleeding from the sclera or choroid at the sclerotomy can be controlled by bipolar diathermy. Care should be taken to avoid scleral shrinkage.

tion or compartmentalization requiring removal (see the next section in this chapter). In the majority of cases, the "core" vitreous requires no specific attention, and the algorithm should proceed to the decision about whether to truncate the PHF or to delaminate ERM first. If the PHF is opaque or semiopaque, it usually requires truncation before the ERM can be delaminated (Fig. 129–10). When there is a partial posterior vitreous detachment (PVD) and the ERM is continuous with sections of the PHF, delamination should precede PHF truncation (Figs. 129–11 to 129–13).

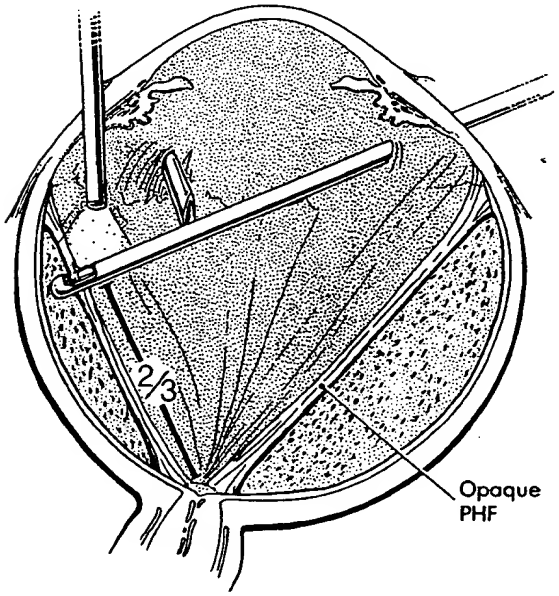


Fig. 129–10. The posterior hyaloid face *(PHF)* should be entered away from the macula and periphery in an area known to be attached or away from the retina. This incision should be extended circumferentially to accomplish truncation.

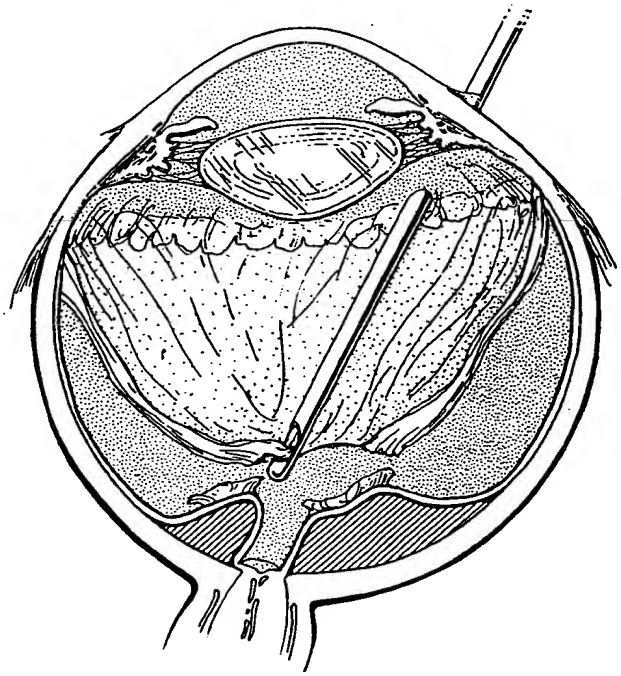


Fig. 129–12. Truncation should precede the extension of an initial full-thickness PHF opening in a safe region. Circumferential 360-degree extension eliminates all anteroposterior traction.

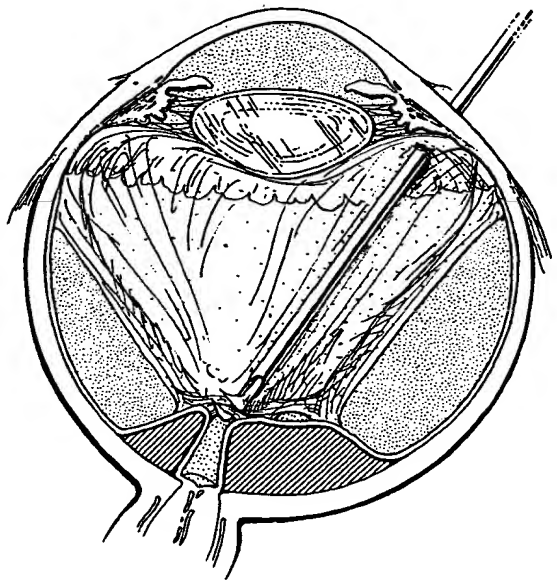


Fig. 129–11. Some initial segmentation can facilitate the preferred inside-out delamination approach. Bimanual and visco dissection should be avoided.

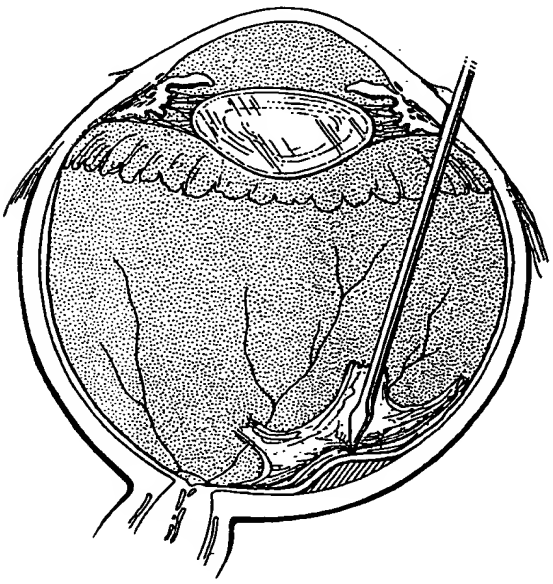


Fig. 129–13. A central edge created by a lancet blade is preferable to seeking an outside edge.

If sub-PHF blood products are encountered while PHF truncation is underway, straight end-opening cannula suction should be used (vacuum cleaning or extrusion) (Figs. 129–14 and 129–15).[20,68]

If, in the process of PHF truncation, elements of PHF are stretched between areas of ERM, they can be resected with the cutter only if it can be done without undue traction on the retina. Inclusive nonsuction shears (power shears or scissors) should be used if these sections of the PHF are taut (Fig. 129–16).

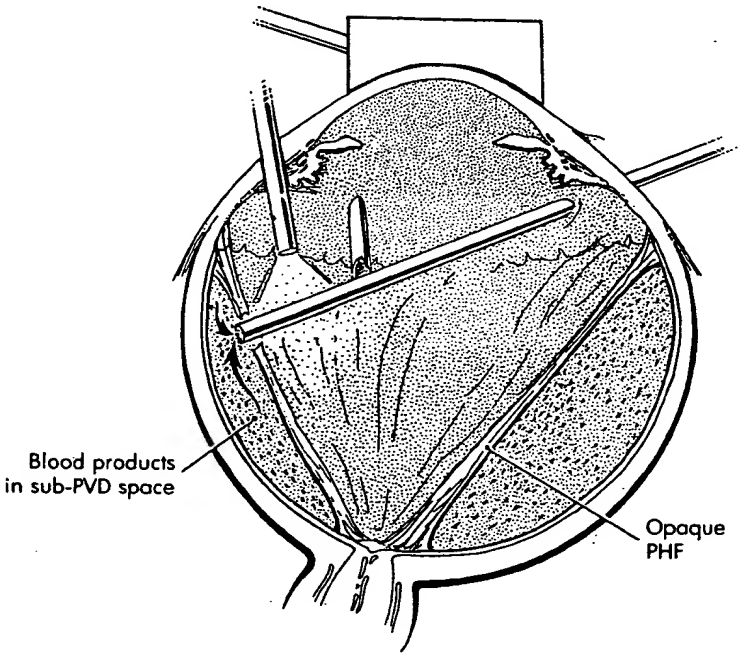


Fig. 129–14. Low, proportional vacuum, rather than a flute needle or cutter, permits safe, nonpulsatile removal of sub–posterior vitreous detachment *(sub-PVD)* blood products.

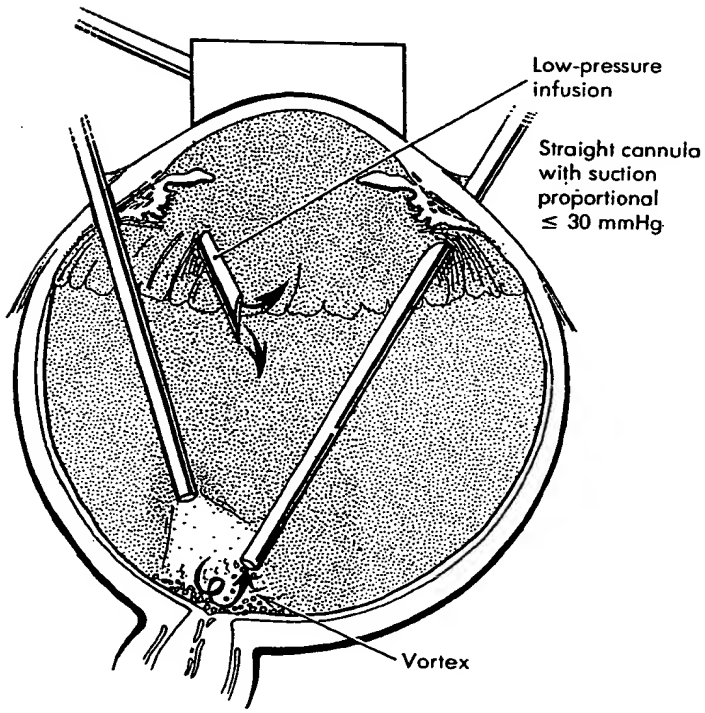


Fig. 129–15. Safe, proportional (foot) controlled suction (30 mm Hg) will readily remove preretinal blood products without retinal damage.

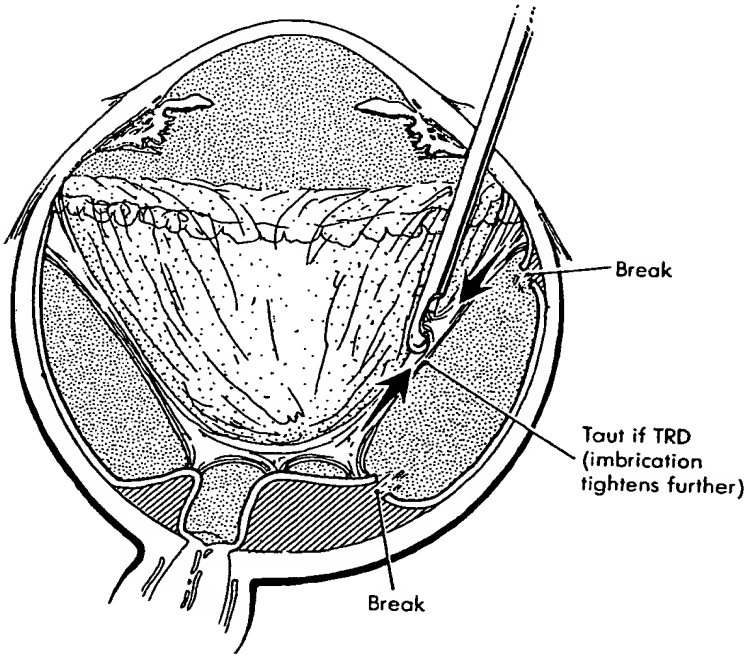


Fig. 129–16. A relatively clear PHF permits inside-out delamination to precede truncation and reduce retinal traction. The delaminated epiretinal membrane (ERM) and contiguous PHF can then be removed in a single process.

Anterior loop traction (ALT) is a significant feature of proliferative vitreoretinopathy (PVR), retinopathy of prematurity (ROP), some trauma, and retrolenticular neovascularization and proliferative diabetic retinopathy (PDR) cases. These cortical fibers are made taut by cellular infiltration extending in the anteroposterior direction from the vitreous base to the pars plana, ciliary body, and even to the posterior iris surface. They can be present from a few degrees up to 360 degrees. ALT must be carefully differentiated from the "skirt" that is left after AHF or PHF truncation, vitreous base, vitreoretinal interface zone, or frontal plane AHF-PHF traction. Anterior loop traction is best visualized with scleral depression by the assistant. Although optical devices exist that facilitate a view of the periphery, scleral depression tends to loosen the anterior loop traction and change the contour. If ALT is broad, it can be resected with a vitreous cutter (suction shear). If it is narrow or especially taut, it should be resected in a circumferential manner with an inclusive shear (power shear or scissors).

LENS MANAGEMENT AND COMPARTMENTALIZATION

In addition to its normal optical function for the patient, the lens affects the management of retinal detachment by vitrectomy. Cells, as well as chemotactic, clotting and mitogenic factors, are retained in the vitreous cavity and thus are exposed to the retina longer in the phakic eye. In the cases of PVR, giant breaks, and trauma, it usually is advantageous to remove the lens to accomplish decompartmentalization of the eye. This also permits better dissection of the ALT, eliminates concern about subsequent cataract surgery, and facilitates dissection under air. In PDR there is a trade-off in that the presence of the lens greatly reduces neovascular glaucoma but allows AHF proliferation (retrolenticular neovascularization), greatly prolongs the retention time of postoperative hemorrhages, and frequently requires subsequent cataract surgery in already ill patients. Lens removal in conjunction with diabetic vitrectomy can be managed with pars plana lensectomy, retention of the anterior lens capsule, and introduction of a posterior chamber lens in front of the capsule. Except for diabetic retinopathy and macular pucker, the majority of vitrectomy patients require lensectomy because decompartmentalization is required.*

Simultaneous sonification and suction using a 20-gauge tool (fragmentor) are a very rapid and efficient way to remove the lens. The method of minimal initial introduction of the tool with the removal of successive layers in a flat plane to avoid anterior and posterior lens capsule is the most efficient. Boring into the lens, infusion into the lens, intermittent suction, and sonification without aspiration should be avoided. Proportional (linear) suction should be used with typical suction levels of 100 to 150 mm Hg while in the capsular bag.[16] If any miosis occurs, scleral depression will facilitate the required removal of all peripheral cortex. A capsulotomy can be made with the sonicator after all cortex is removed. The majority of the capsule should then be removed with the

*References 10, 33, 36–40, 74, 80.

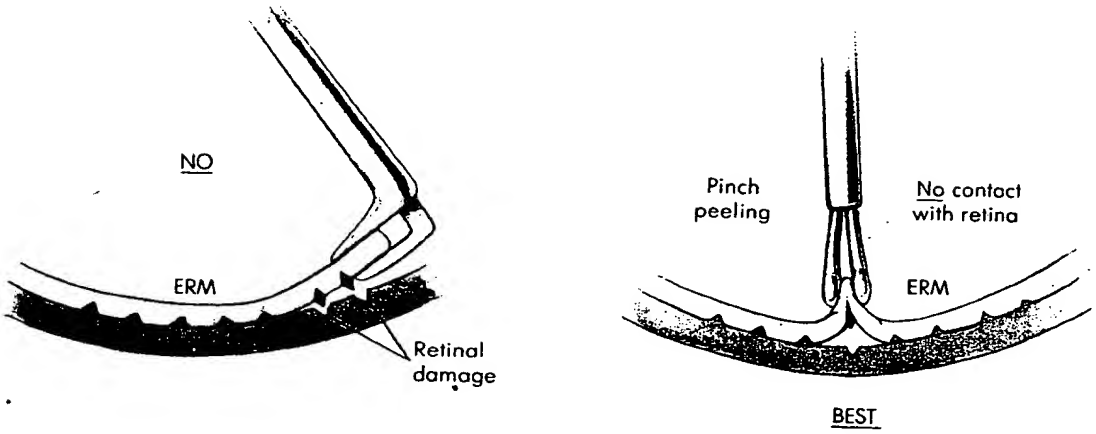


Fig. 129–17. Bent needles, picks, side-opening forceps, and visco dissection damage the retina. Less adherent membranes are removed by end-opening forceps without retinal contact. More adherent membranes require inside-out delamination.

end-opening forceps. Removal of all capsule prevents the inflammation and peripheral proliferation associated with the retention of lens material. Circumlinear traction reduces vitreoretinal traction.

All forms of intraocular lenses should be removed for PVR and giant break cases. Their removal should be accomplished by making a posterior shelving, limbal incision with a sharp blade, injecting viscoelastic into the anterior chamber, and completing dissection with scissors for 100 to 160 degrees. It is important not to distort or damage the cornea so as to have excellent visualization later in the procedure. Anterior chamber lenses are easily removed by depressing the scleral edge at the site of the haptic. Fortunately, iris plane lenses are unusual now. They frequently require scissor sectioning of the haptics and iris sutures for safe removal. Most posterior chamber lenses can be removed by gentle rotation and haptic depression, but some require sectioning of the haptics to avoid traction on the ciliary body, which may result in subsequent bleeding. The wound should be closed with a multiple x type 9-0 monofilament suture to prevent wound leaks and intraoperative astigmatism. All viscoelastic should be meticulously removed with the vitreous cutting tool or suction cannula because of the adverse effect it has, such as retaining mitogens, cells, and chemotactic factors and decreasing the interfacial tension of silicone. Residual capsule, cortex, and associated fibrous proliferation should be completely removed, as described earlier to reduce inflammation and peripheral proliferation.

ERM MANAGEMENT

The decision node in ERM management has three branches. The ERM can be removed by elongation (peeling), segmentation, or delamination (inclusive shear). The membrane can be segmented to release tangential forces and retained. Choices are somewhat disease dependent in that PDR usually, and ROP always requires delamination. PVR requires peeling in most early, less adherent cases, with segmentation or delamination used in later, denser and more adherent cases (Figs. 129–17 to 129–21).*

The central biologic issue is to minimize trauma to the internal limiting lamina (ILL) and to reduce reproliferation while eliminating all tangential force from the retina, bleeding, and reproliferation resulting from retained ERM. The problem of damage to the ILL can be reduced by better inclusive shears or nonthermal laser delamination. Smaller tools and better, more stable microscopetable systems would facilitate visualization and removal of thinner membranes (Fig. 129–22).

SUBRETINAL PROLIFERATION MANAGEMENT

Subretinal proliferation can be placoid, dendritic, or annular in configuration. Because the biologic behavior seems to be less likely to result in reproliferation, subretinal membrane removal is dictated by geometric reasons. If the retina cannot be reattached with an undistorted macula without removal of subretinal membrane, subretinal surgery is indicated (Fig. 129–23).

Subretinal surgery can be divided into elongation (peeling) and inclusive shearing (segmentation, scissors). If a retinal break is appropriately positioned, forceps of varying angles can be used to grasp and remove long dendrites with a sequential regrasping technique. If the membrane is placoid, elongation also can be used.

*References 18, 19, 26, 32, 59, 76, 78.

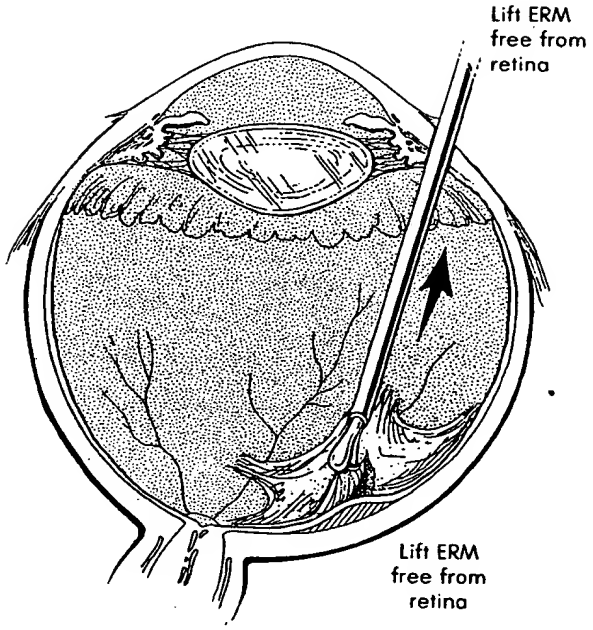


Fig. 129–18. End-opening forceps peeling with retinal contact is used for less adherent epimacular proliferation (EMP) and proliferative vitreoretinopathy (PVR).

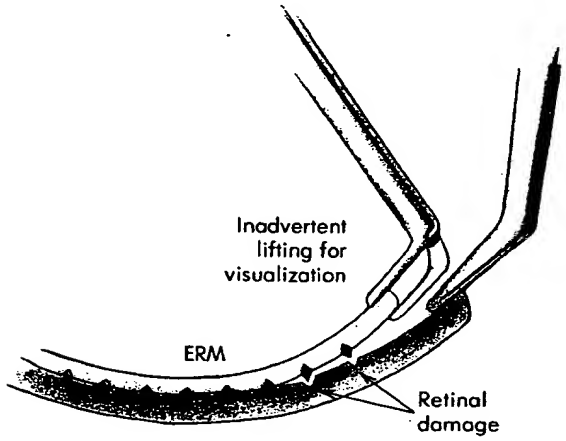


Fig. 129–19. The desire to view the dissection by lifting the ERM while delaminating causes unnecessary retinal traction and damage.

At times, dendrites are very adherent or are connected to vascularized areas, and segmentation is more appropriate (Fig. 129–24). Shearing retinotomy without tissue removal should be used with either method if no appropriate retinal break is present.

NONCUTTING SUCTION TECHNIQUES

Various configurations of tapered or nontapered, curves, straight, or silicone rubber equipped suction devices can be used to remove material from the eye (vacuum cleaning, extrusion). End-opening 20-gauge cannulas with low suction levels are used to remove free blood products or small particles of lens material from the retinal surface or from within the eye. Proportional (linear) suction at very low levels (5–40 mm Hg) should always be used.

Tapered cannulas that are bent or small flexible silicone tubing cannulas can be used for internal drainage of subretinal fluid. The algorithm for internal drainage of subretinal fluid begins with drainage, then fluid-air exchange with continued or repetitive internal drainage of subretinal fluid.

SURFACE (INTERFACIAL) TENSION MANAGEMENT

Air (gas) interface with water provides 72 dynes/cm^2 of surface tension. Silicone is approximately 40 dynes/cm^2. Hyaluronic acid, chondroitin sulfate, and lipoproteins from blood or inflammation lower the interfacial tension to about 30 dynes/cm^2 when in contact with the surface of the silicone oil bubble.

Surface tension management is far more significant than buoyancy effects provided by air, gas, or silicone. The purpose of these agents is to eliminate transretinal hole fluid flow, thus restoring a transretinal pressure gradient.

Silicones and gases recompartmentalize at the retinal surface (and iris surface) (Fig. 129–25). These substances increase reproliferation at these sites because of retention of cells and cell-cell interaction factors. The best silicones are those with the highest resistivity, lowest vapor pressure, higher viscosity, and higher average molecular weight.

An inferior peripheral iridectomy allows aqueous to enter the anterior chamber from below and, it is hoped, keeps the silicone away from the cornea. At least 20% of these cases develop corneal problems in spite of the iridectomy, as well as subacute angle closure (2%), and emulsification glaucoma is now zero. The incidence of glaucoma increases from 15% in the first year to more than 50% in long-term follow-up.[5,8]

Silicone tamponades unseen retinal breaks and retinal breaks that occur after surgery. It is also useful in retinopexy avoidance to reduce reproliferation with large area breaks or retinectomies.[14,17,75]

Fluid-air exchange

Air, for surface tension management, should be injected through the infusion cannula while simultaneously removing intraocular and subretinal fluid with noncutting techniques as described earlier (Fig. 129–26). Constant pressure pumps control intraocular pressure, are nonpulsatile, and can provide large flow rates to compensate for wound leaks. Incremental retinectomy and

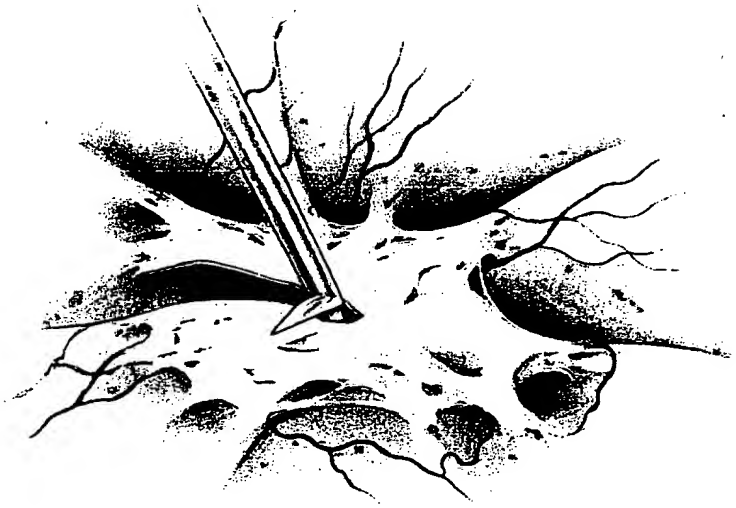


Fig. 129–20. Inside-out segmentation of starfolds eliminates peeling and produces the least retinal damage and reproliferation.

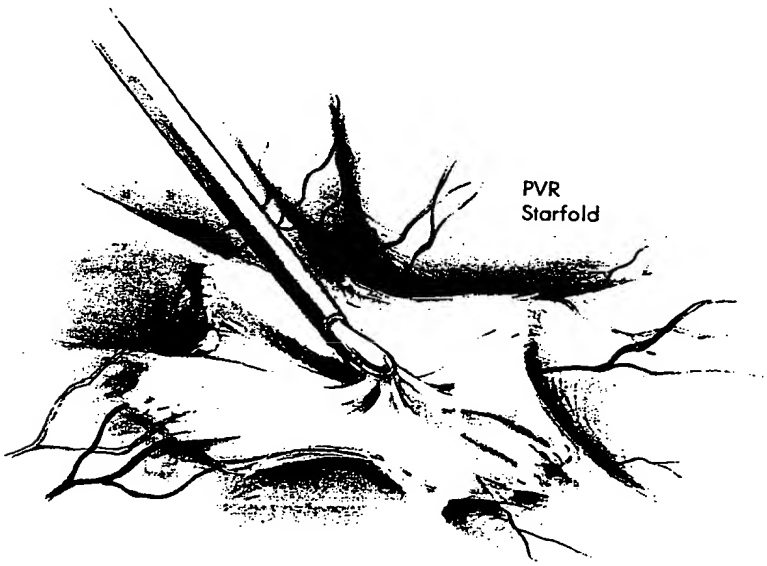


Fig. 129–21. End-opening forceps peeling reduces retinal damage and is used for most less adherent starfolds.

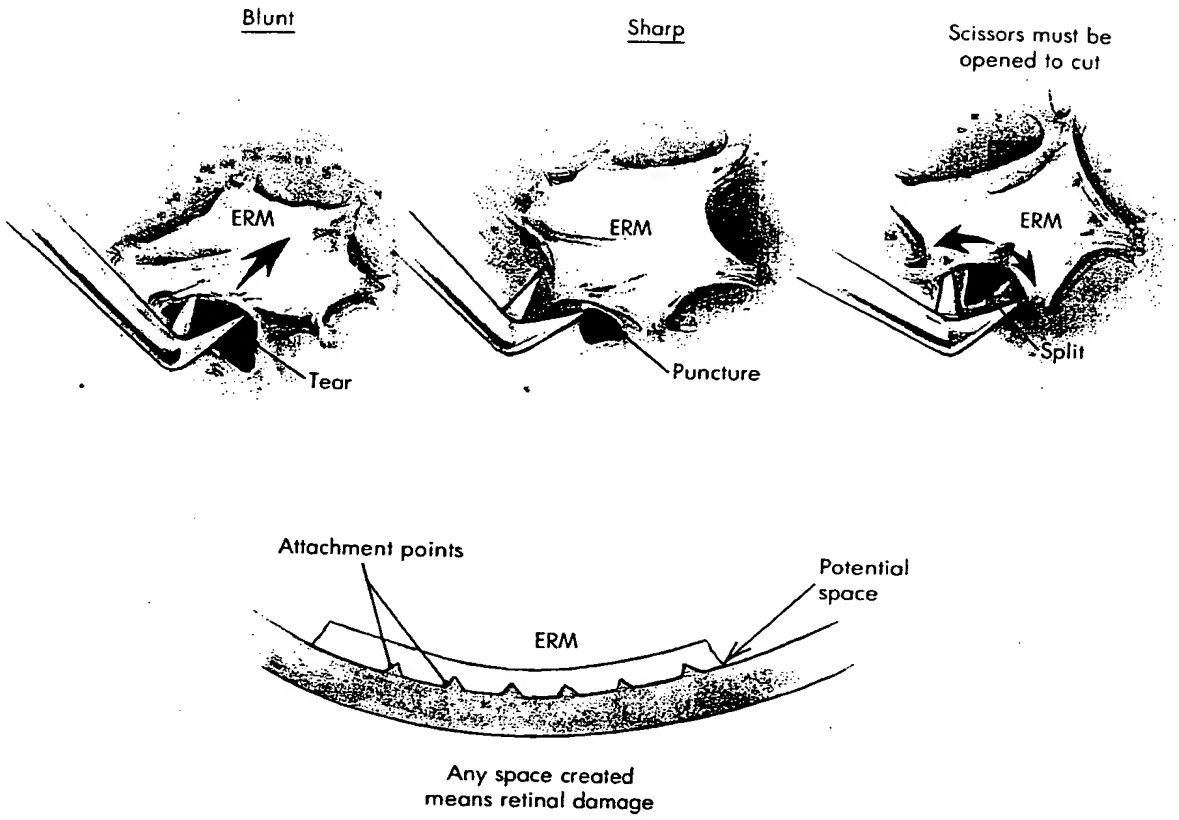


Fig. 129–22. Pointed scissors can penetrate retina during delamination of proliferative diabetic retinopathy (PDR) ERMs, whereas blunt scissors push tissue away. Spreading without cutting should be avoided as well.

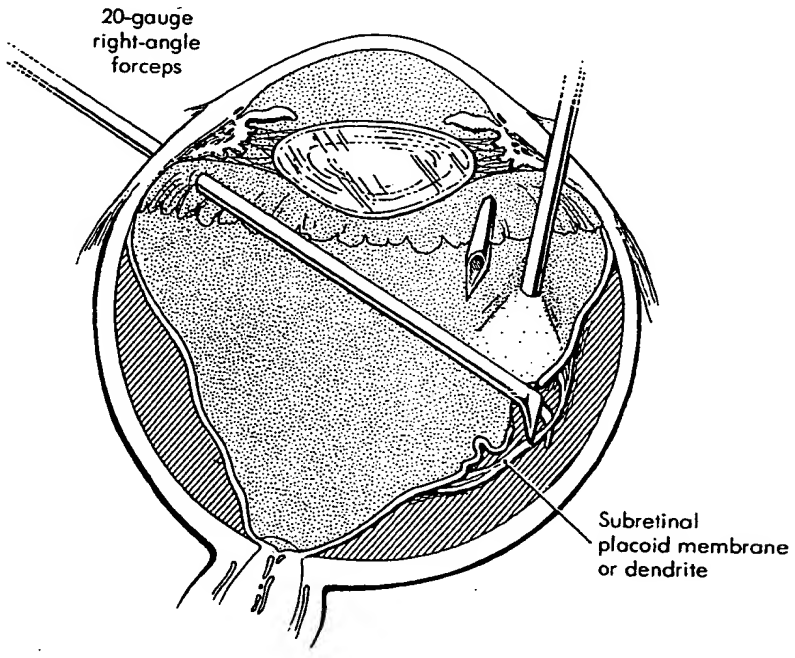


Fig. 129–23. Right-angle, long forceps can be passed through a preexisting break or linear retinotomy to remove subretinal dendrites or annular structures.

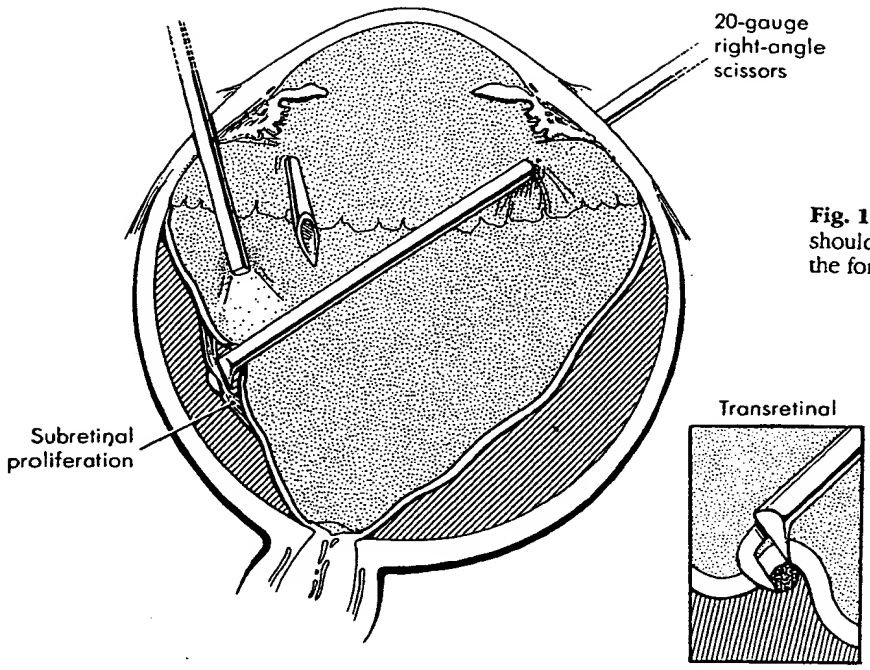


Fig. 129–24. Fibrous subretinal proliferation should be segmented rather than removed with the forceps.

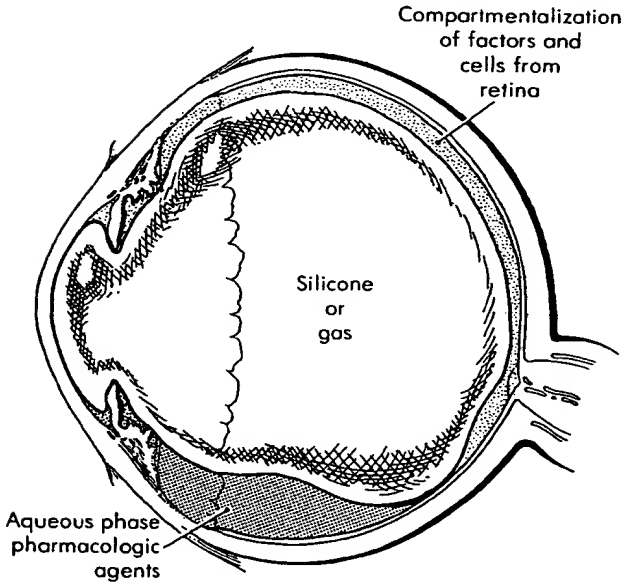


Fig. 129–25. Air/gas and silicone sequester cells and factors at the retina, increasing reproliferation. Lenses and intraocular lenses reduce egress rates of cells and factors from the vitreous cavity and increase reproliferation.

further delamination, peeling, or segmentation can be performed under air surface tension management.

Air-gas exchange

If a long-acting gas is chosen to maintain surface tension until retinopexy takes effect, it should be injected in the desired final concentration through the infusion cannula after fluid-air exchange. The air is aspirated with constant low suction near the optic nerve to ensure complete exchange and accurate gas concentration (Figs. 129–27 and 129–28). Power volumetric injectors should be used for this purpose. Injecting aliquots of gas into an air-filled eye provide little control over concentration and subsequent bubble size because of unknown ocular volume.*

Air-silicone exchange

Because air has a higher interfacial tension than does silicone, fluid-air exchange with internal drainage of subretinal fluid to reattach the retina should precede silicone infusion. Silicone should be injected with a pressure controlled power injector through a short 20-gauge straight cannula or through the infusion cannula with very short tubing. The air can be removed by proportional aspiration until the silicone reaches the pupillary plane. Infusion fluid should be used to reform the anterior chamber if it becomes flat. Hyaluronic acid lowers the silicone interfacial tension and should not be used to deepen a flat chamber.

RETINECTOMY

Retinectomy should be performed only incrementally after fluid-air exchange and internal drainage of subretinal fluid (SRF) (Fig. 129–29). If subretinal air appears as

*References 1, 2, 15, 21–23, 25, 26, 29, 34, 35, 44, 49–54, 57, 62, 66, 67.

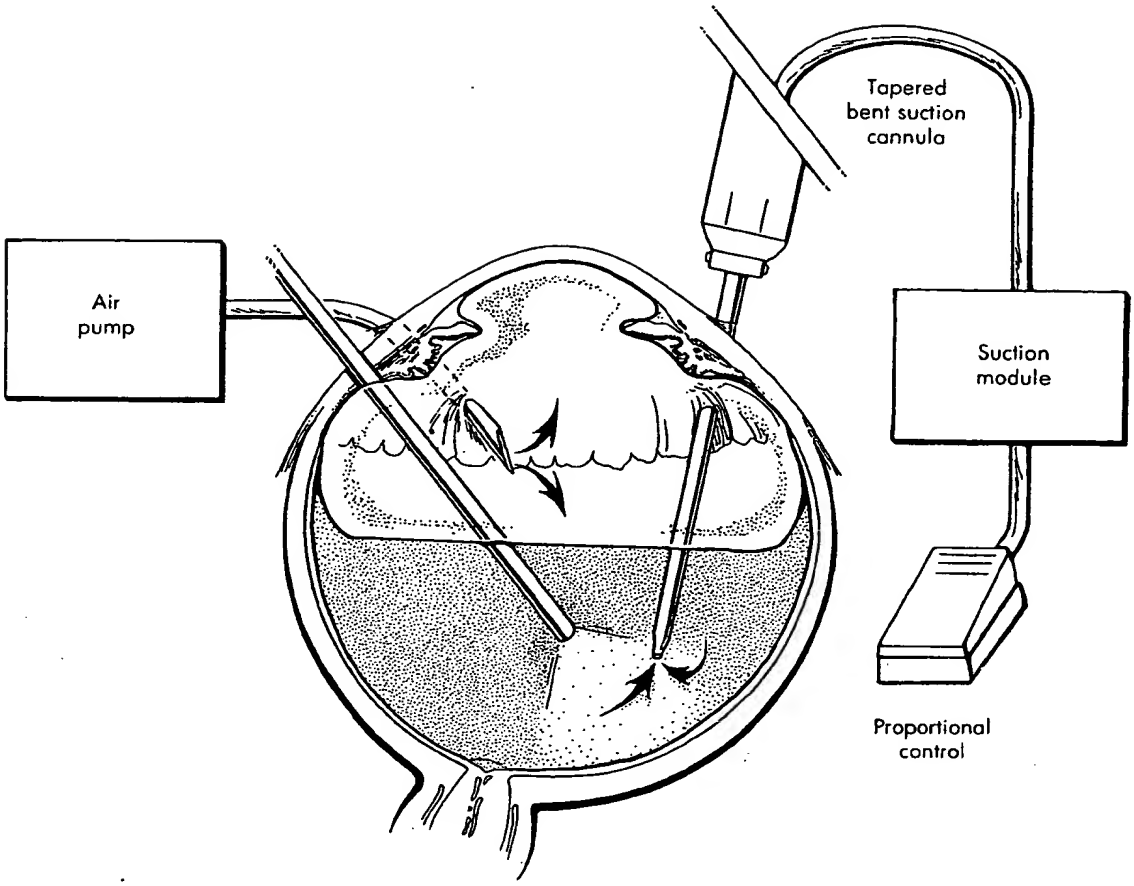


Fig. 129–26. An air pump infuses air through the infusion cannula and maintains intraocular pressure while fluid is removed with proportional suction cannulas.

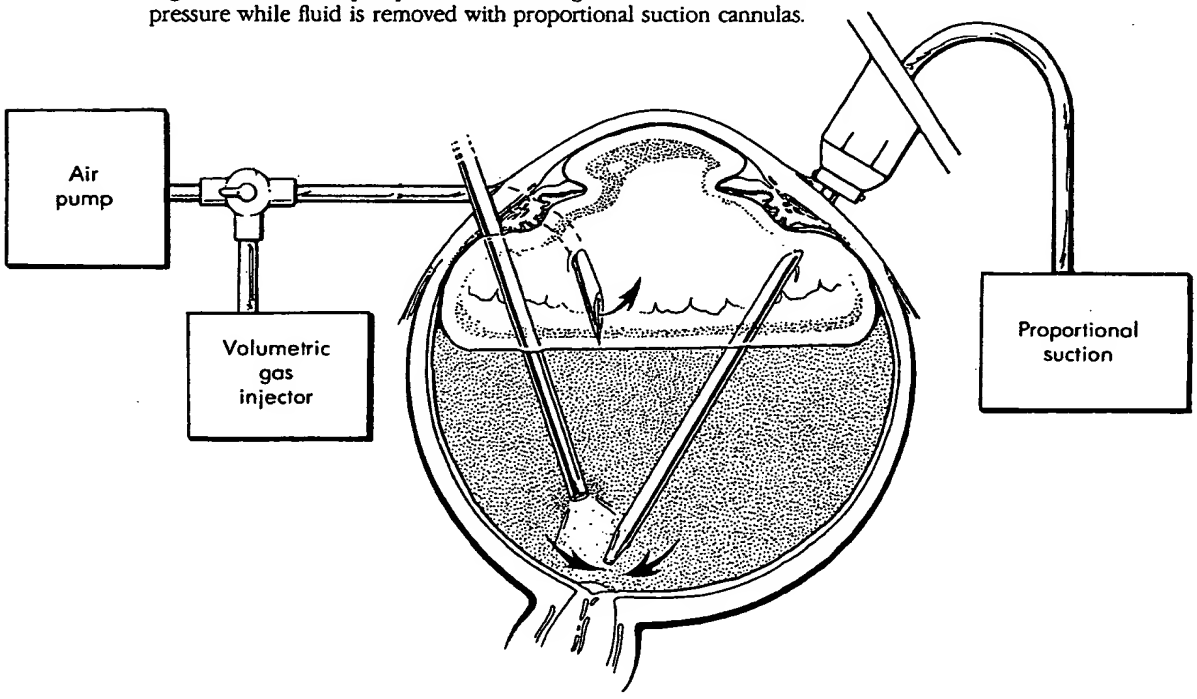


Fig. 129–27. Volumetric gas injection combined with proportional air evaluation allows total exchange and correct gas concentration.

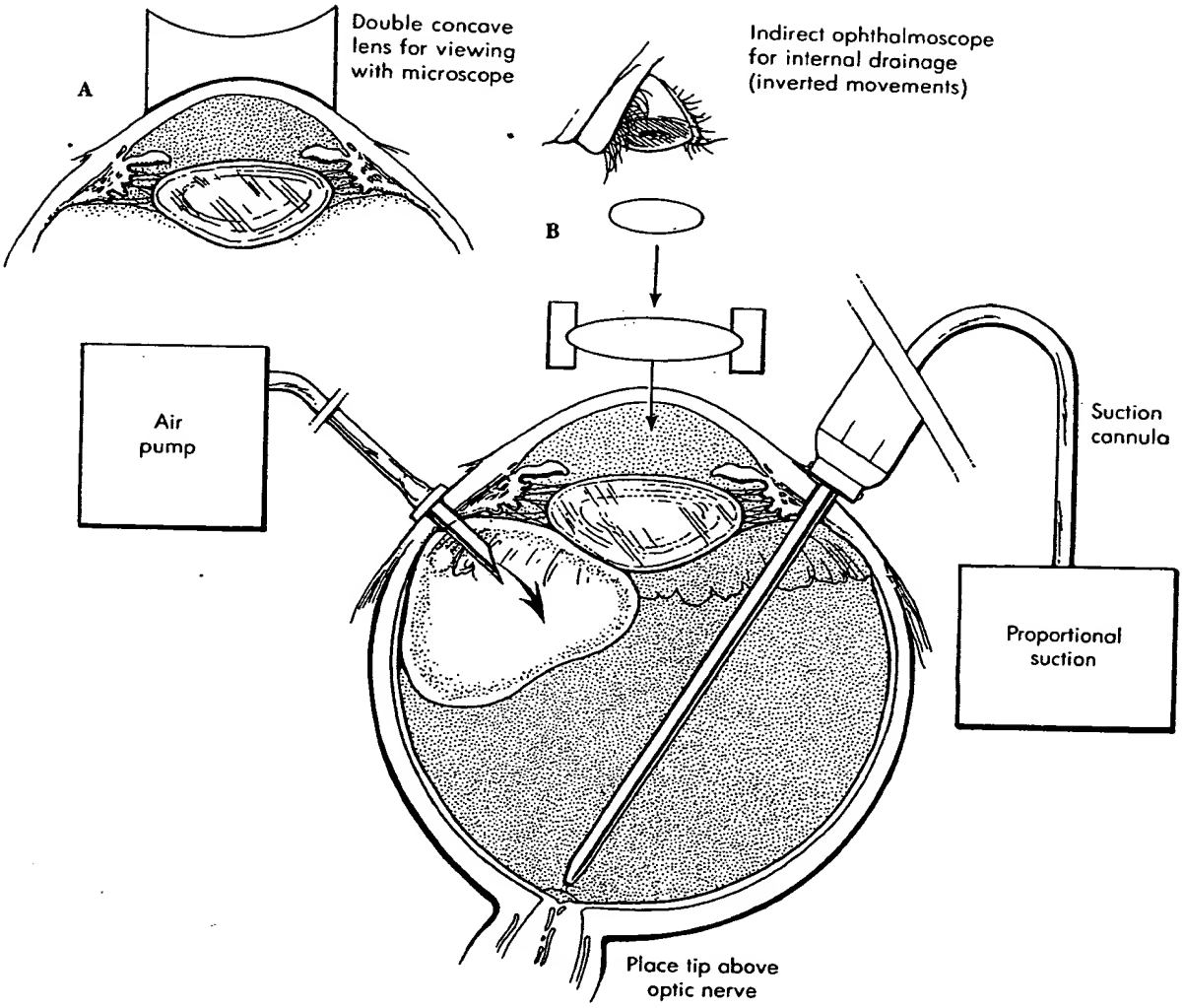


Fig. 129–28. A, High minus contact lenses are the preferred method of visualization during phakic fluid/gas exchange. **B,** Indirect ophthalmoscopes are used if this is not available.

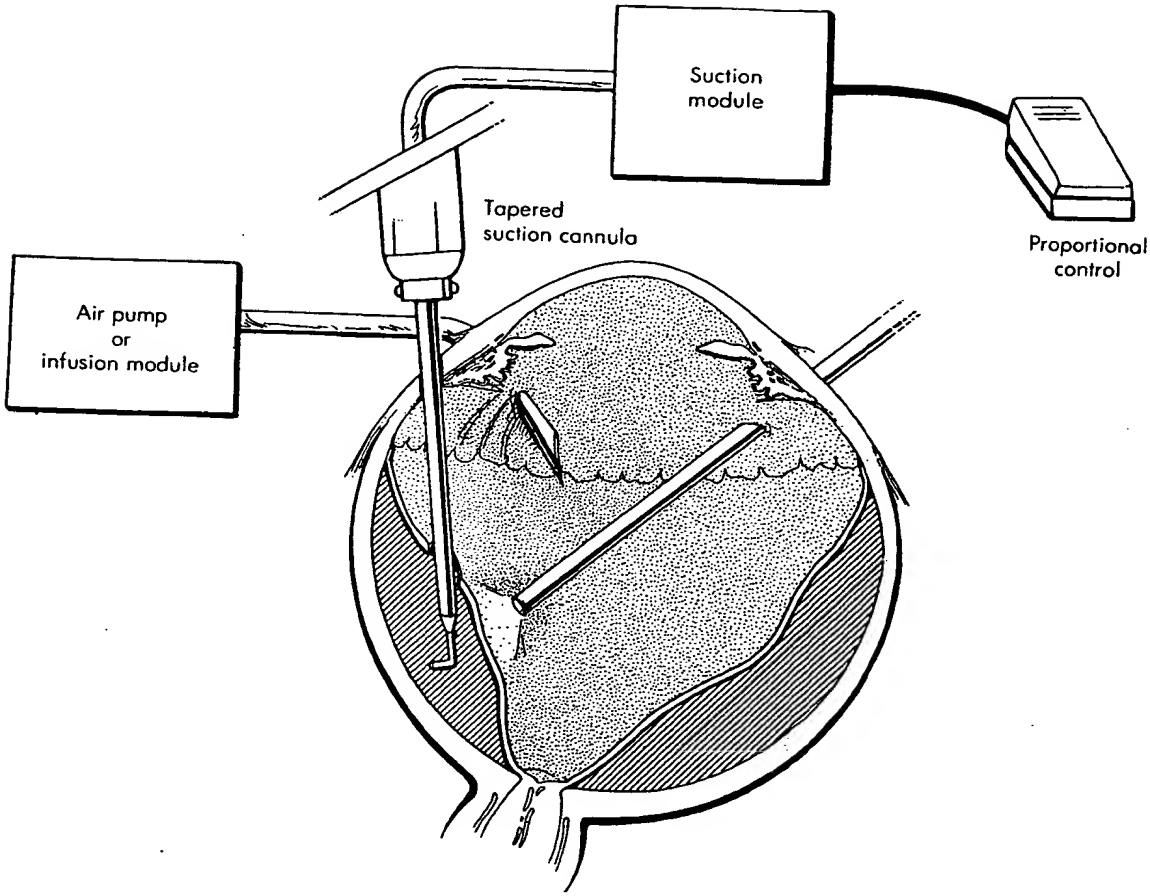


Fig. 129–29. Tapered bent suction cannulas held near the RPE and controlled by proportional (foot) suction allow safe internal drainage of subretinal fluid.

internal drainage of SRF is slowly proceeding, the subretinal air location indicates retinal traction or retinal foreshortening. Further vitrectomy, delamination, subretinal surgery or scleral buckling may be required at this point. If this seems not to be needed, retinectomy will be required to manage the foreshortening or residual traction. This should be done incrementally with inclusive power shears or scissors until the retina is reattached. Retinectomy performed under fluid is difficult and frequently results in excessive retinectomy. Thermal laser retinotomy causes retinal damage, again inciting reproliferation. Large vessels should be pretreated with 1-mHz bipolar RF thermal coagulation. Tacks, retinopexy, and retinoplasty will be discussed later.

CONTROL OF BLEEDING

Transient (±5 minutes) elevation of intraocular pressure, preferably with a servo system, is the best means of controlling intraoperative bleeding. Rapid elevation of intraocular pressure when bleeding is noted will prevent extensive, tenacious preretinal blood clots. Holding the intraocular pressure between capillary and diastolic arterial pressure can be used while dissecting vascular epiretinal membrane attachment areas. The intraocular pressure should be normalized in a few minutes after clotting occurs. Any areas still bleeding should be treated with unimanual bipolar endo 1-mHz RF thermal coagulation (Fig. 129–30). This should be combined with a 20-gauge endoilluminator for convenience and to prevent bleeding from transient intraocular pressure decrease during instrument change. Laser endophotocoagulation is also useful for this purpose, with the choice made by the presence of retinal elevation (Fig. 129–31). Pretreatment of vascular areas with RF or laser results in retinal necrosis, prolongs the procedure, and causes unnecessary coagulation of the tissue to be removed.[43,79]

PERMANENT RETINAL-RPE ADHERENCE

Retinopexy (cryo, RF, laser), tacks, incarceration, suturing, and retinoplasty (glue) all have been used to create

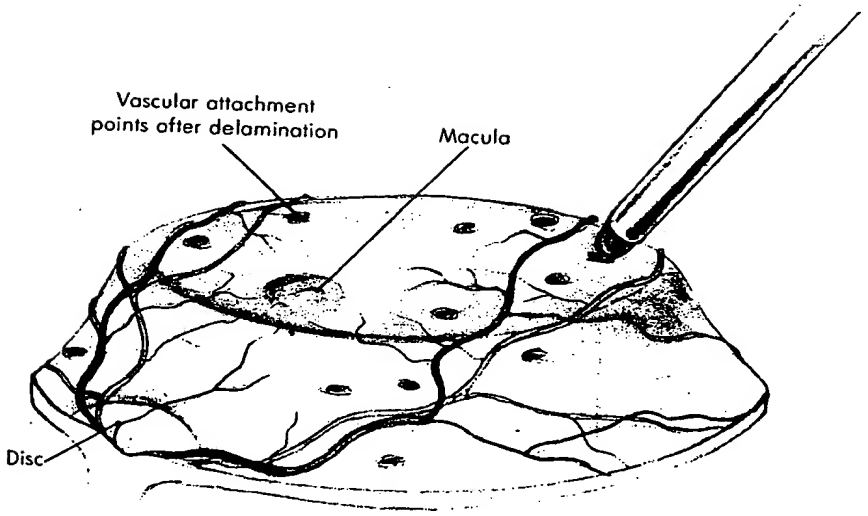


Fig. 129–30. Unimanual bipolar 1-mHz radiofrequency is used for all elevated bleeding vessels.

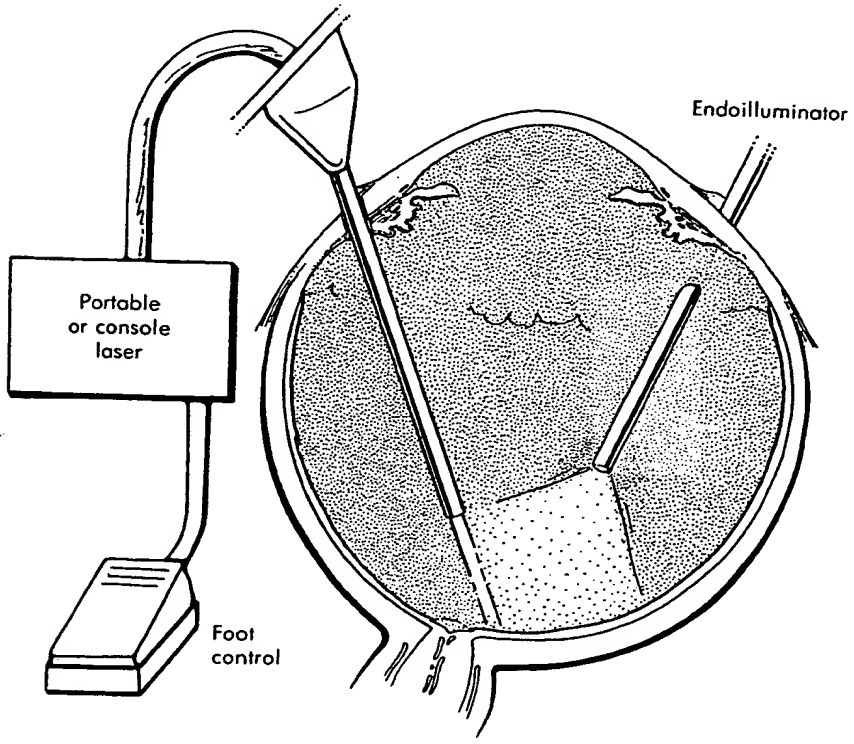


Fig. 129–31. Laser (argon, krypton, or diode) endophotocoagulation under fluid or air is used for retinopexy, panretinal photocoagulation, and flat focal bleeding.

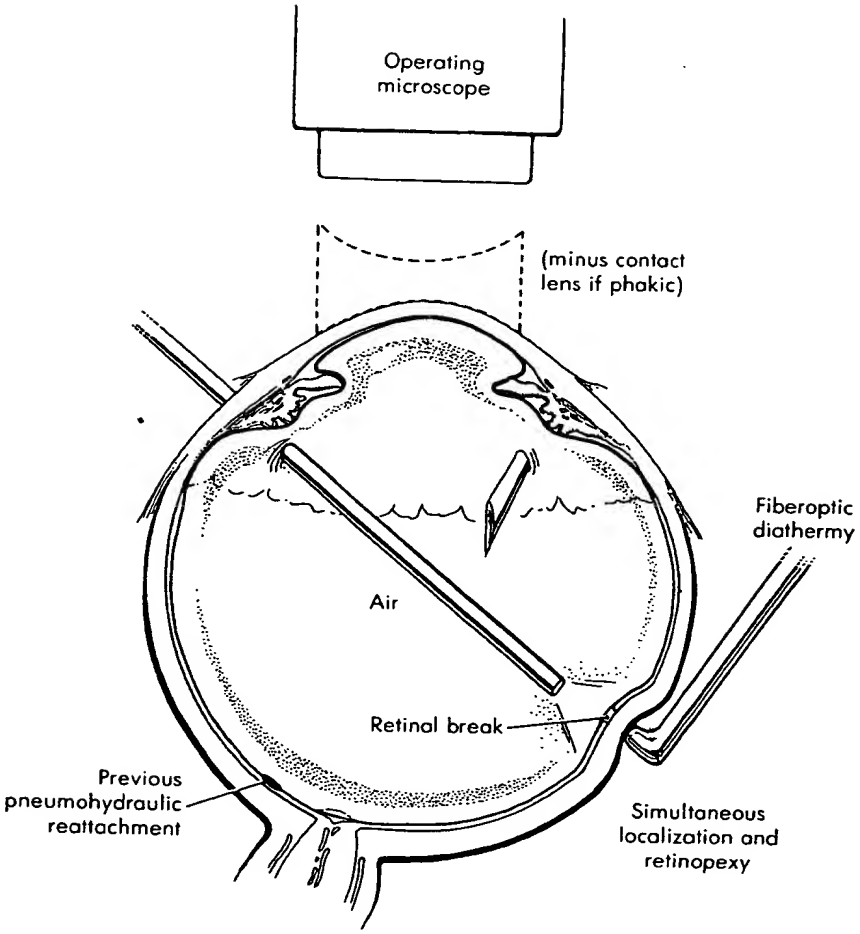


Fig. 129–32. The operating microscope and contact lens can be used for visualization while the small fiberoptic diathermy performs retinopexy. Air-filled eyes reduce scleral damage.

permanent retinal-RPE adherence (Figs. 129–32 and 129–33). Suturing and incarceration create too much distortion, bleeding, and reproliferation from tissue damage. Tacks are no longer used because they cause distortion, pull through the retina as reproliferation occurs, damage all layers (retina, RPE, choroid, and sclera), cause bleeding, and occasionally dislocate.

All forms of retinopexy create tissue destruction and reproliferation and should be used as little as possible. Continuous (painting) laser endophotocoagulation is preferable to intermittent circular retinopexy lesions because more uniform tissue destruction and tensile strength result. Panretinal photocoagulation should be used only for vasoproliferative retinopathy, not for PVR. Cryopexy causes more proliferation than laser or diathermy and should be avoided in vitrectomy surgery.

Retinoplasty prevents the need for tissue destructive retinopexy, tacks, gas, and silicone. A bionormal retinoplasty substance should greatly reduce the monumental problem of reproliferation secondary to surgical intervention. The ideal substance would be bionormal (i.e., spray-on ILL-retina polymer). This would reduce cellular migration, restore transretinal pressure gradient, reduce bleeding, and have elasticity greater than or equal to the retina. Cyanoacrylate is difficult to use; the monomer is carcinogenic and mildly exothermic and has excessive rigidity. The goal is restoration of continuity, hence the term retinoplasty, rather than creation of retinal-RPE adherence, that is, retinopexy.*

PANRETINAL PHOTOCOAGULATION

Argon, dye, krypton or, preferably, diode (semiconductor) laser can be used for panretinal photocoagulation. It reduces vasoproliferative factor production, causes the RPE to release an inhibitory substance and increases choroidal oxygen transport to the retina.[4,71] It is hoped that inverted Gaussian power density beam will be developed to produce uniform thermal profile and reduce reproliferation and tissue destruction.

*References 3, 6, 7, 28-32, 45, 67, 68, 77

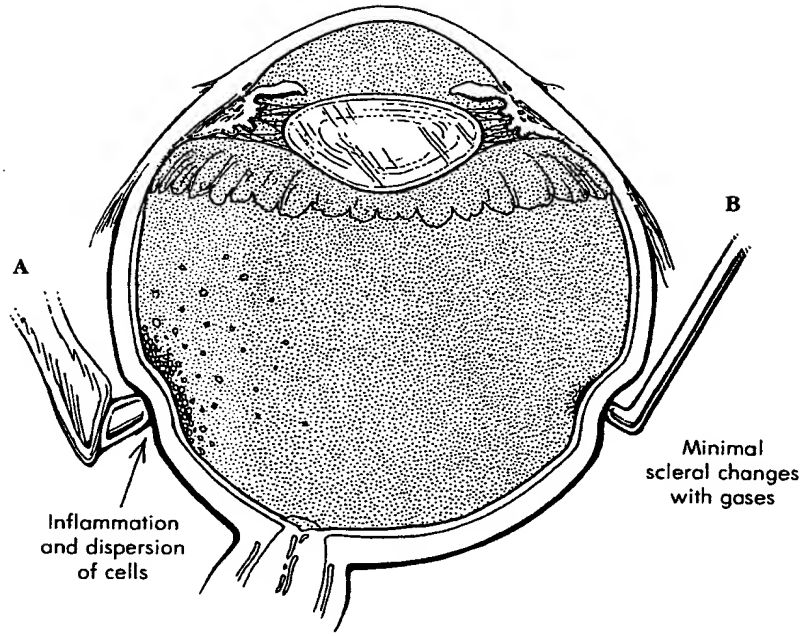


Fig. 129–33. A, Cryo disperses viable RPE cells and changes the blood-retinal barrier, increasing proliferation. **B,** Transscleral diathermy creates minimal scleral changes and no dispersion of RPE cells.

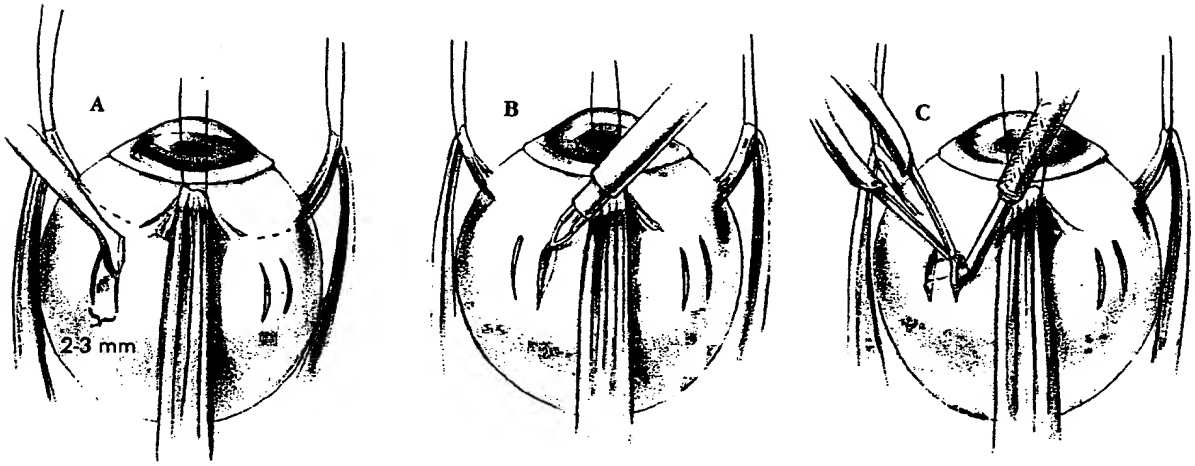


Fig. 129–34. A, Two radial cuts of one-half scleral thickness are made in each quadrant. **B,** Light cautery is applied to bleeding vessels at belt-loop incisions. **C,** Belt loops are completed by intrascleral dissection along the tissue plane created at half-scleral thickness.

SCLERAL BUCKLING FOR VITREORETINAL SURGERY

Silicone exoplants with circumferentially oriented monofilament nylon sutures with limbus-parallel scleral bites, or belt loops, are recommended for vitreoretinal surgery. Sponges create subconjunctival bulging, with subsequent dellen formation and extrusion. They more frequently result in infection for this reason and because of interstitial spaces. Sponges and other distensible buckles create an irregular buckle contour with resultant retinal folds and possible SRF leakage.[41,65,72]

Scleral belt loops at the equator, made with radial keratotomy blades with depth guards and right-angled, round-tipped disposable knives, are useful for encircling

bands (Fig. 129–34). Belt loops cause equal tension in each quadrant, are faster to create, and prevent suture pull-through and buckle migration. A No. 240 encircling band with belt loop is recommended for all PDR cases (Fig. 129–35).

Portions of a 9-mm nongrooved silicone exoplant are excellent as circumferential buckles, just as the same material with butt joint buried 5-0 nylon sutures is recommended for encircling tires for PVR and giant breaks (Fig. 129–36).

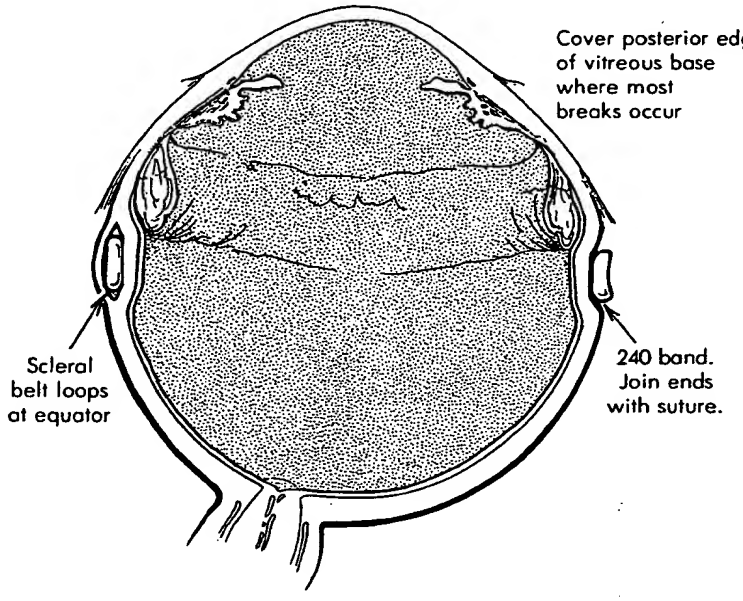


Fig. 129–35. The No. 240 band tied with a double passed supramid suture in the superonasal quadrant.

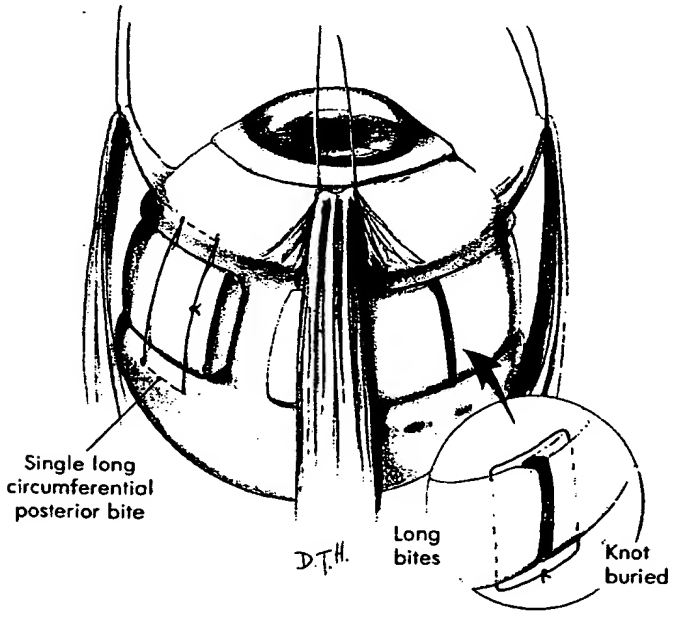


Fig. 129–36. For PVR and giant breaks, 9-mm silicone exoplants with two 5-0 nylon mattress sutures per quadrant are used. Limbus parallel bites with anterior bites in the muscle ring reduce retinal perforation.

SCLEROTOMY SUTURES

Monofilament 8-0 nylon sutures offer the best compromise between tensile strength and leakage caused by larger-needle diameters. Monofilament nylon or equivalent sutures are elastic and close a wound that has opened because of undue pressure on the globe. Inelastic sutures, such as silk, should not be used. Absorbable sutures cause wound leaks and inflammation from the absorption process. A running shoelace suture with three bites for a typical 1.4-mm 20-gauge sclerotomy is fast and easy and offers tight wound closure (Fig. 129–37).

CONJUNCTIVAL CLOSURE

Running 6-0 plain gut sutures for the 2-mm limbus based flap closure eliminate postoperative conjunctival foreshortening and redundancy. Suturing of Tenon's to the muscle insertion causes ptosis, limitation of ocular motility, and inadvertent conjunctival incisions during reoperation (Fig. 129–38).

SUBCONJUNCTIVAL PHARMACOTHERAPEUTICS

Subconjunctival antimicrobials for gram-negative bacteria and Penicillinase-producing *Staphylococcus* should be used after all vitrectomies. A subconjunctival steroid injection should be used in all cases unless the patient is known to have corticosteroid-induced glaucoma or has immune deficiency. The use of subconjunctival antiproliferative agents is discussed in Chapter 142.

SURGICAL ALGORITHMS

Earlier portions of this chapter provided an intellectual framework of physical, biologic, and surgical principles. Each of the surgical scenarios has been illustrated graphically and described. The combination of these scenarios into a surgical algorithm is disease-state dependent, and indications and specific management of disease states are left to other chapters. Algorithms for each common disease state follow.

SUMMARY

Conservative indications, aggressive use of the best biooptic and electrooptic technology and careful follow-up are required for optimal results in vitreoretinal surgery. Continued improvements in instrumentation and methodology are needed for vitreoretinal surgeons to achieve better results in managing the diseases that have such high recurrence rates and such tragic outcomes.

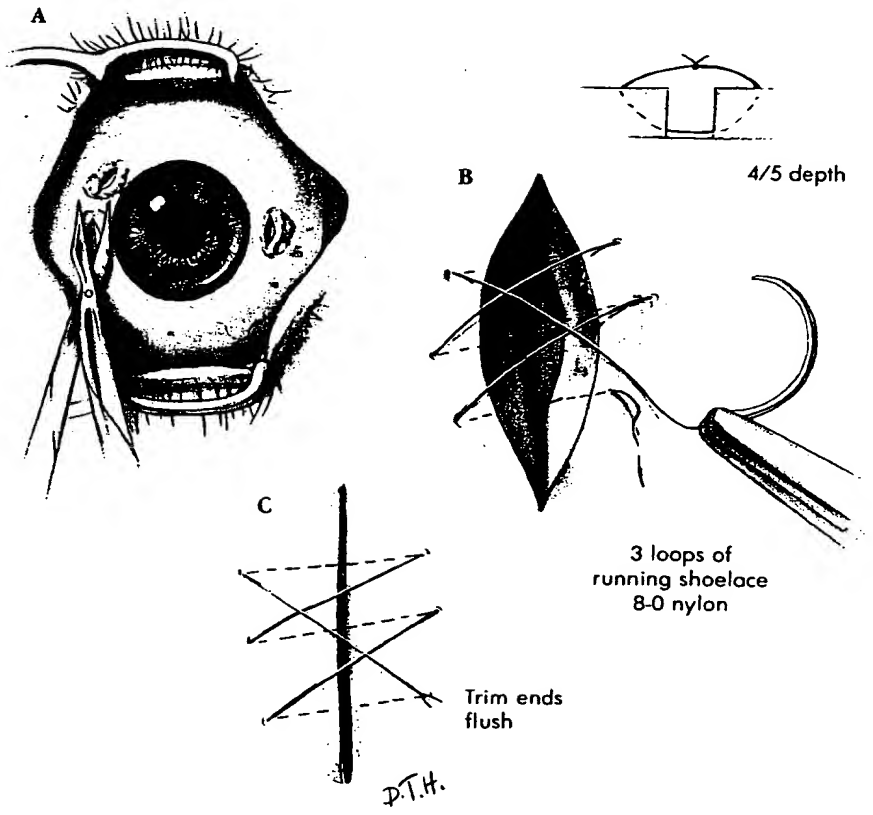


Fig. 129–37. Sclerotomies should never be treated with cryo or diathermy. **A,** Prolapsed vitreous should be trimmed flush with the surface of the sclera without applying tractional forces on the exposed vitreous. **B,** Sclerotomies are closed with 3-4 bite running shoelace 8-0 nylon suture, placed at four-fifths depth in the sclera. **C,** Suture is trimmed flush with the knot.

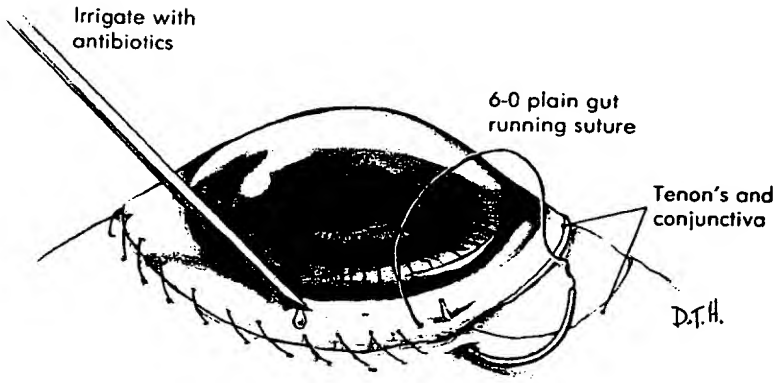
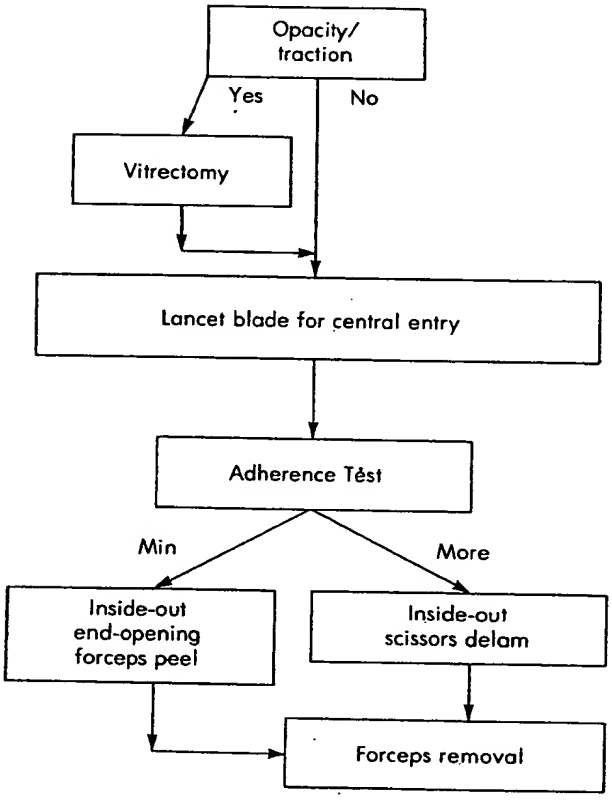
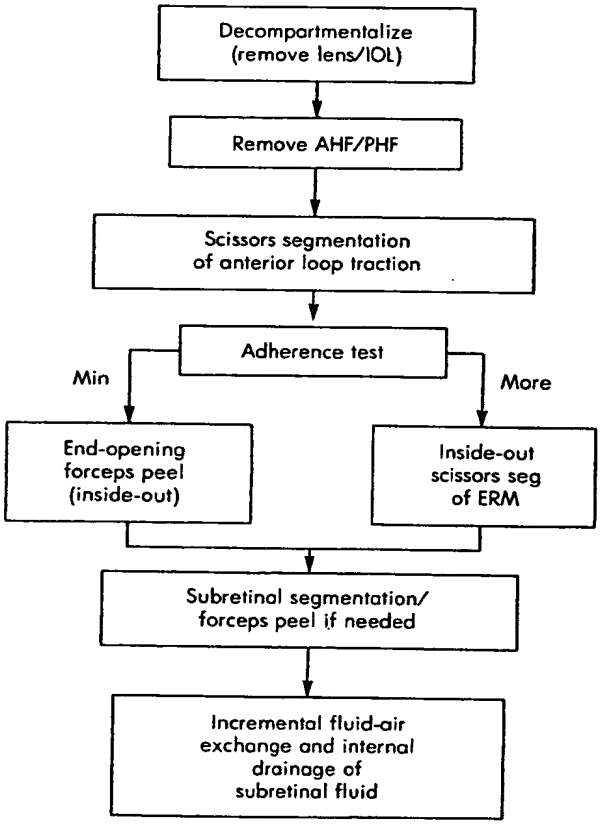


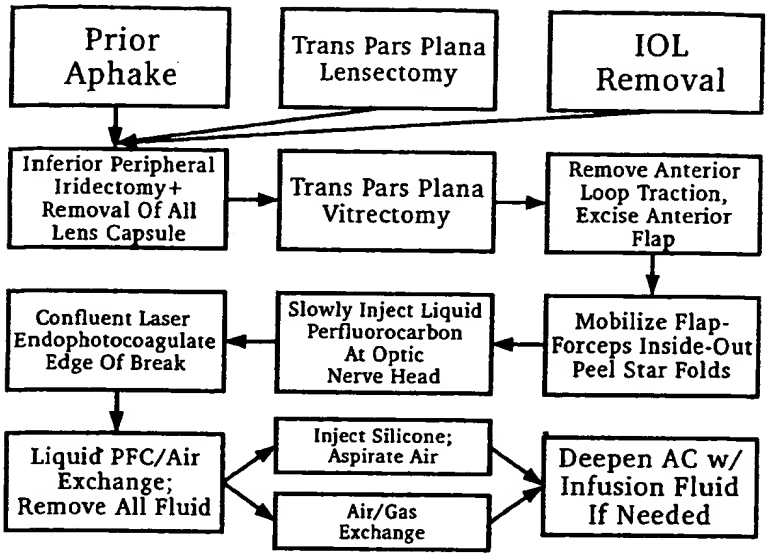
Fig. 129–38. A single running 6-0 plain gut suture should be used to close Tenon's and conjunctiva in a single layer.



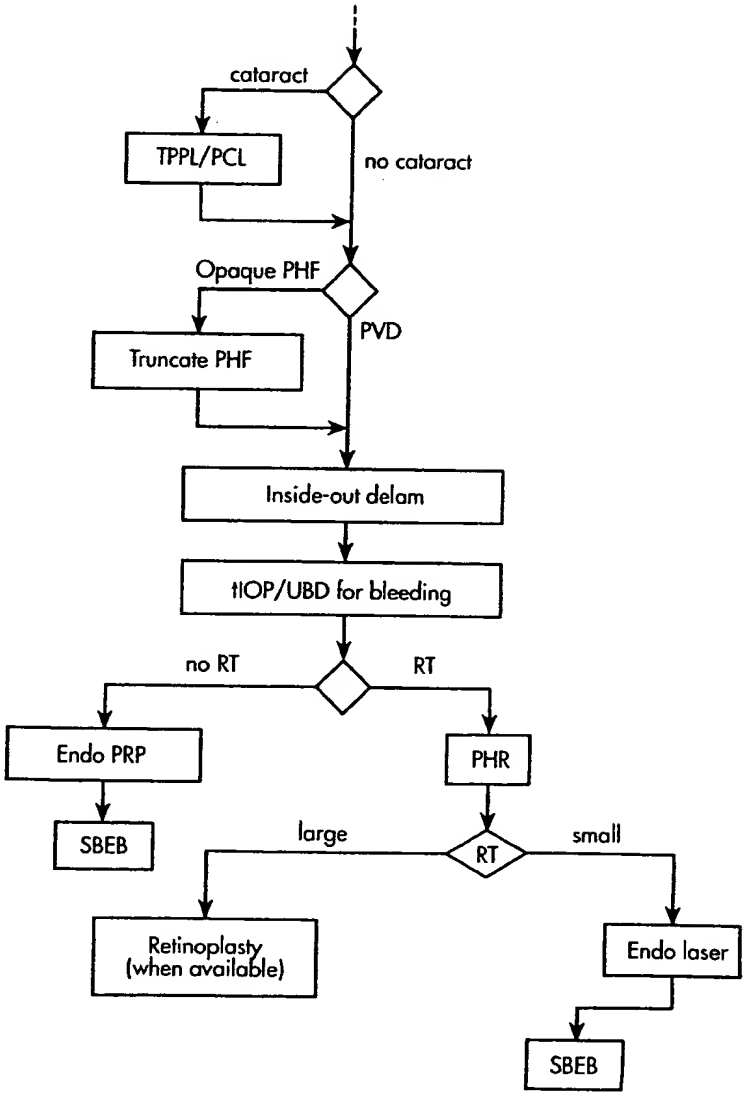
Algorithm 129–1. For management of EMP.



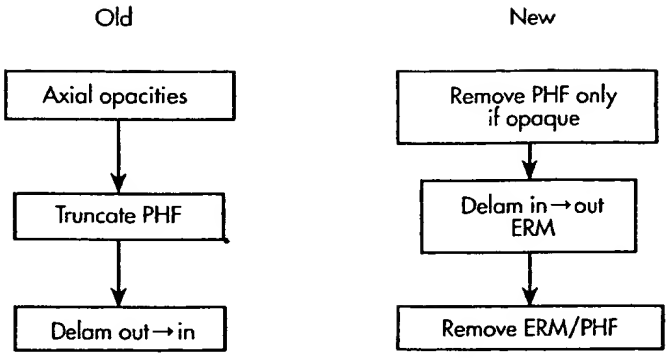
Algorithm 129–2. For management of PVR.



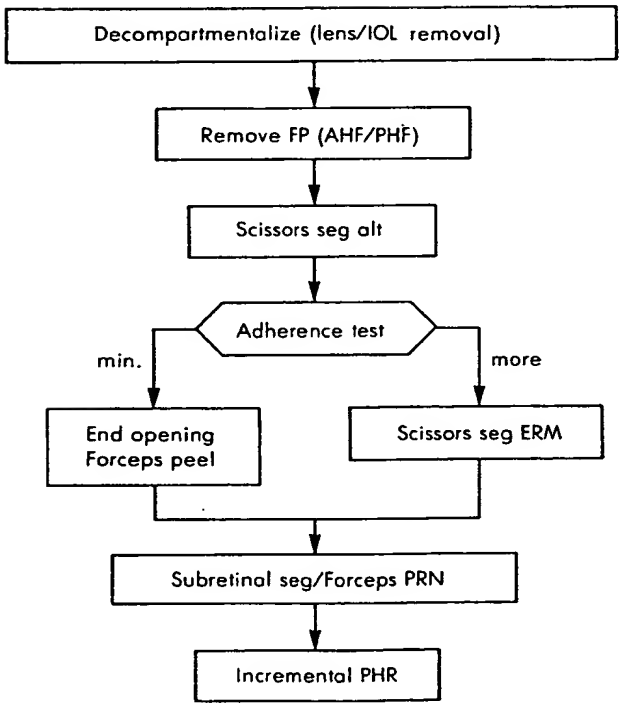
Algorithm 129–3. For giant breaks.



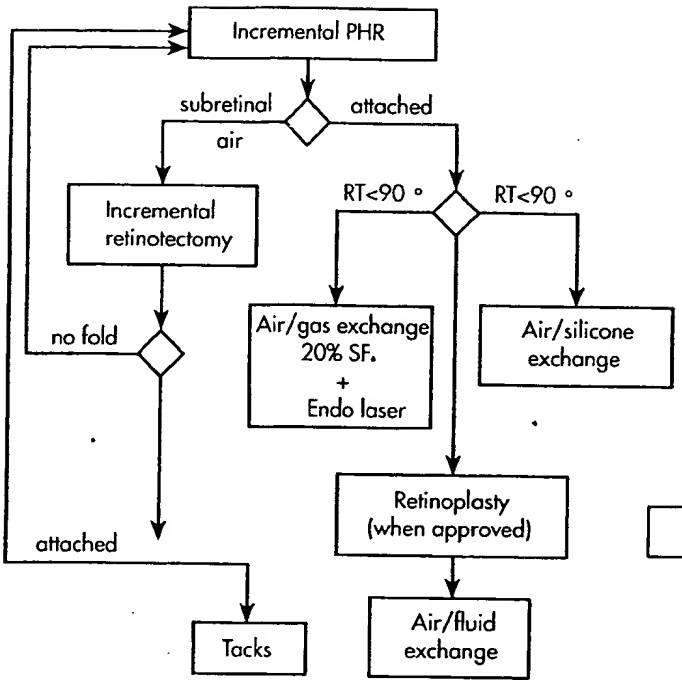
Algorithm 129–4. For PDR.



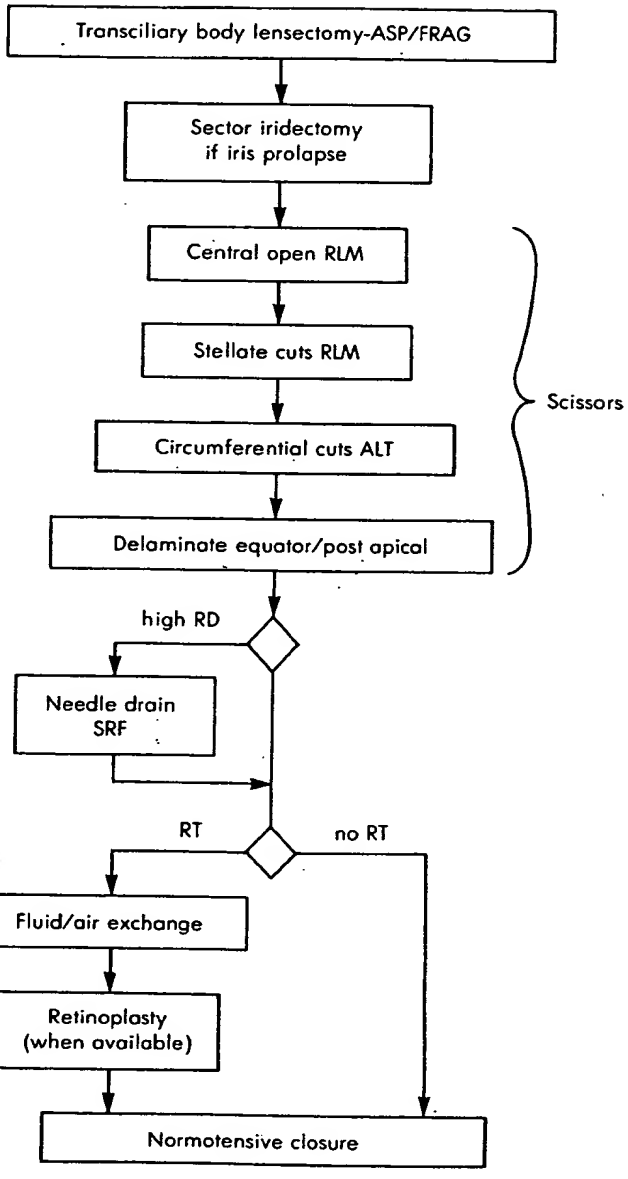
Algorithm 129–5. For PDR



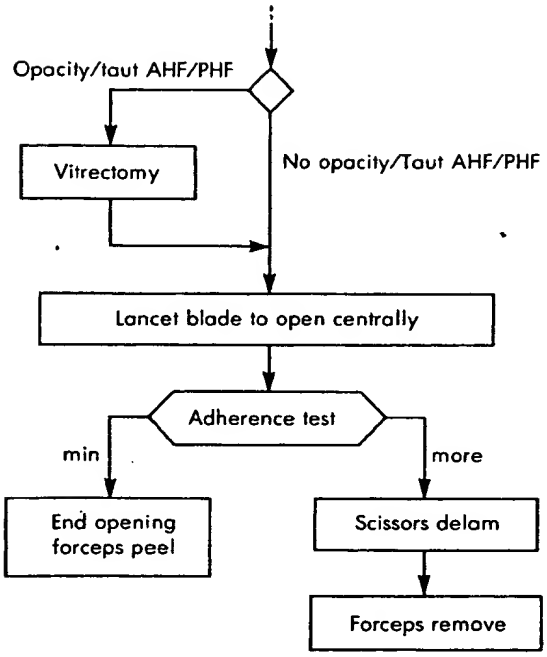
Algorithm 129–6. For PVR



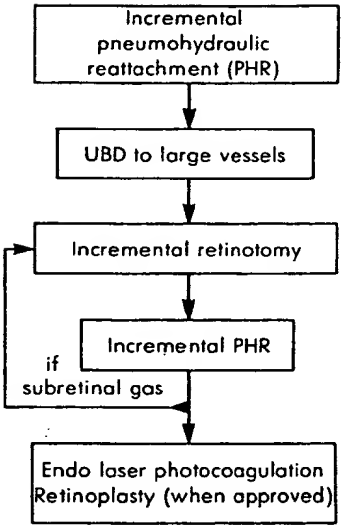
Algorithm 129–7. For PVR



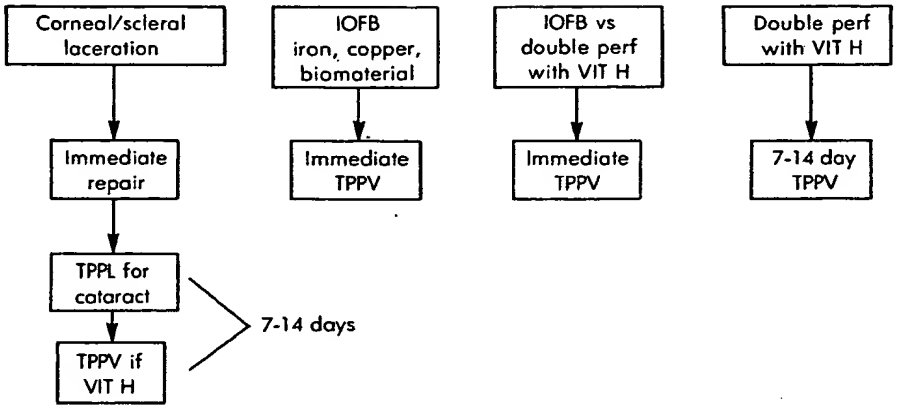
Algorithm 129–8. For retinopathy of prematurity.



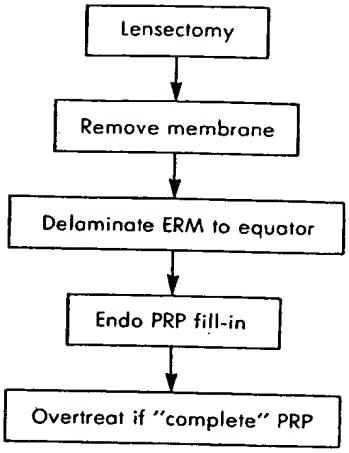
Algorithm 129–9. For EMP.



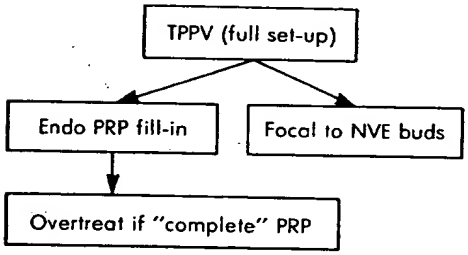
Algorithm 129–10. For retinotomy.



Algorithm 129–11. For trauma.



Algorithm 129–12. For retro-lental neovascularization.



Algorithm 129–13. For rebleeding.

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Retina – 3rd Edition

Chapter 127

Principles and Techniques of Vitreous Surgery

Steve Charles

Vitreoretinal surgery is a complex blend of the most difficult high-technology microsurgery applied to a complex pathobiologic system. This relatively new and rapidly growing field requires continuous research and training and an honest assessment of one's surgical skills, knowledge, and experience. The surgical team must be well trained, efficient, and technologically competent; the complex equipment must be constantly maintained and updated as the technology progresses.

To help deal with the complexity of vitreoretinal surgery, I propose an approach that uses surgical algorithms for various scenarios. The surgical scenarios are similarly composed of smaller elements referred to as tools, associated analog parameters (pressure, power, and so forth), and digital interconnects (fluid-gas exchange, air-silicone exchange, and the like). Scenarios are common to the surgical approach to different disease states that share common pathoanatomic configurations. Each algorithm contains decision nodes with several alternative scenarios. The decision process requires outcome data, knowledge of physical principles, individual patient factors, and experiential information. This chapter first describes relevant general pathoanatomy, with specific information being left to other chapters on specific disease states. Understanding the mechanics of the tools used will allow discussion of the details of how to perform the steps dictated by each scenario. The chapter concludes with a series of suggested algorithms for each common disease state, with specific management details again left to other authors.

VITREORETINAL SURGICAL ANATOMY

The vitreous can be considered as a three-dimensional matrix of collagen fibers and hyaluronic acid gel (Fig. 127-1). In the normal state, the outer surface of the vitreous is in contact with the retina, pars plana, and ciliary body in a roughly spherical shape, with an anterior facet for the lens. Disease-induced cellular infiltration against a background of age-related changes causes hypocellular gel contraction of the collagen matrix, with most of the relevant changes occurring at the cortex level. The anterior vitreous cortex (AVC) is continuous with the posterior vitreous cortex (PVC) and, for the most part, is a nonfenestrated surface.

Abnormal retinal glial cells, retinal pigment epithelial (RPE) cells, and cells of hematogenous origin migrate along the front and back surfaces of the retina and vitreous. These cells have coated pits lined with fibronectin, allowing them to attach to and contract the collagen matrix.*

A detailed understanding of the abnormal vitreoretinal interface and its derivative geometry is requisite to undertaking vitreoretinal surgery. The task involves visualization of vitreous and periretinal membranes to be removed and a systematic search for membranes based on observed retinal topology. In general, membranes are white and have a matte finish, whereas the retina has a surface luster and appears pale yellow. If a complete posterior vitreous separation has not occurred, there is usually continuity between areas of epiretinal membrane (ERM) and adjacent detached PVC. Because the retina itself does not contract or sustain intraretinal proliferation, changes in contour occur because of perpendicular or oblique vitreous traction (funnel, plateau, or ridgelike elevations) or tangential periretinal membrane traction (starfolds and puckers).

Retinal breaks result in a relative decrease in or loss of the normal transretinal pressure gradient. Transhole flow is related to intraocular pressure (IOP), capability of the RPE

*References 9, 11-13, 45-48, 55, 56, 58, 60, 61, 77, 82.

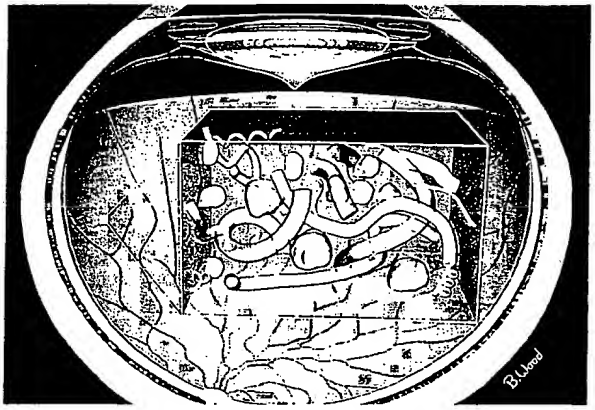

Fig. 127-1 The vitreous is a three-dimensional matrix of collagen fibers and hyaluronic acid gel.

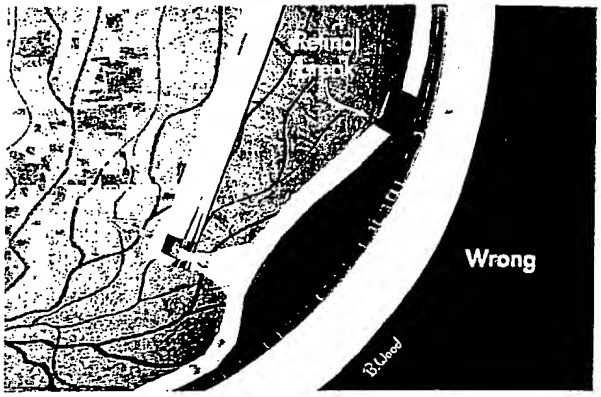

Fig. 127-2 Rapid withdrawal of a cutter with entrapped tissue can tear the retina.

pump, viscosity of the fluid, and the size of the retinal break.[15,16]

MECHANICS OF VITREORETINAL SURGERY

An understanding of the physical principles of surgical tools enhances the capabilities of the vitreoretinal surgeon. Discussion of the forces available for cutting and thermal effects follows. Cutting may be defined simply as the separation of a tissue into two parts.

Elongation

Force along the axis of a collagen fiber bundle causes collagen fibers to fail. Damage to attached structures is a function of the number of fibers and the strength of the attachment and the substrate. Membrane peeling or stripping requires force perpendicular to the retina that causes failure of the attachment at the vitreoretinal interface by elongation. Because the membranes are approximately 100 times stronger than the retina,[81] failure of the retina usually occurs before failure of the membrane.

Shear

Shear occurs when force is applied along two opposing parallel planes moving toward each together. Vitrectomy cutters and scissors use shear to cut tissue. Inclusive shears, such as a vitreous cutter, prevent the extrusion force that occurs as typical exclusive shears (scissors) close, pushing the tissue away from the blades.

Fatigue Failure

Fatigue failure occurs when repetitive motion, elongation, and compression weaken tissue structure and cause failure. Ultrasonic cavitation (fragmentation and emulsification) is an example of this mode of cutting.

Fig. 127-3 Suction should be controlled with a proportional foot pedal to reduce undue traction.

VITREOUS CUTTER CONSIDERATIONS

All current vitreous cutters use suction and inclusive shearing. Ideal tissue cutting is defined as that which produces no displacement of the tissue, no thermal damage, and no acoustic effects. The lowest suction force sufficient to place tissue in a position to be sheared is the safest (Figs. 127-2 to 127-4). If the inner cutter has high velocity, the port acts as if it is open most of the time, resulting in nonpulsatile fluid flow and less vitreoretinal traction (Figs. 127-5 to 127-7). High-speed travel of the shear uses the inertia of the tissue to change apparent mass and facilitate cutting (Fig. 127-8). In summary, low suction, high cutting velocity and frequency, and large ports (Fig. 127-9) provide the safest cutting. Maintaining approximation of the cutter inner and outer members is required to prevent tissue tearing associated with a misaligned shear.

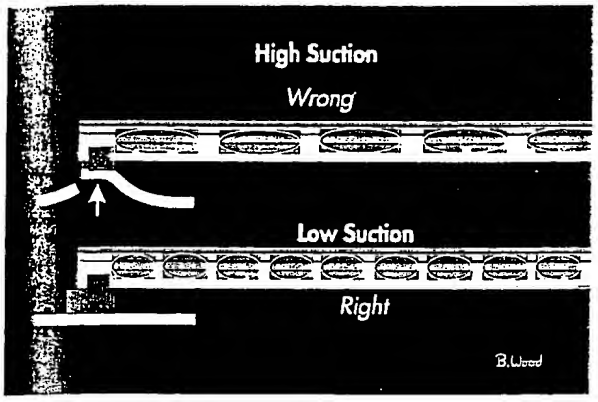

Fig. 127-4 The lowest effective suction force is the safest.

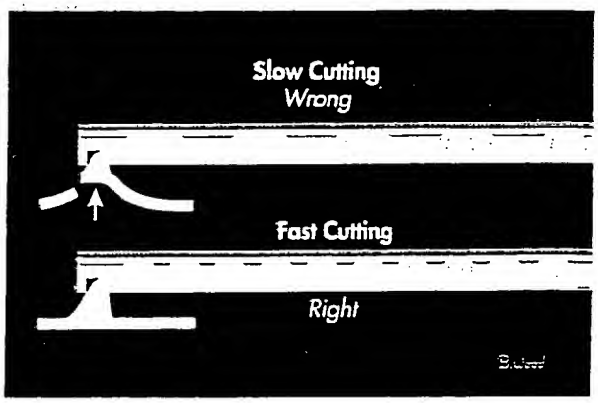

Fig. 127-5 High velocity of the inner cutter results in nonpulsatile fluid flow and reduced vitreoretinal traction.

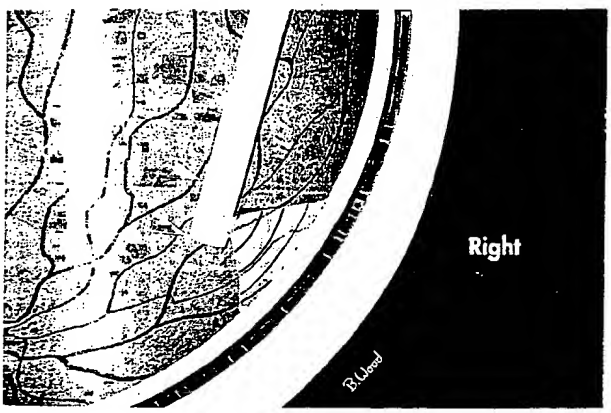

Fig. 127-6 Moving the cutter toward the tissue to be cut minimizes the suction force needed.

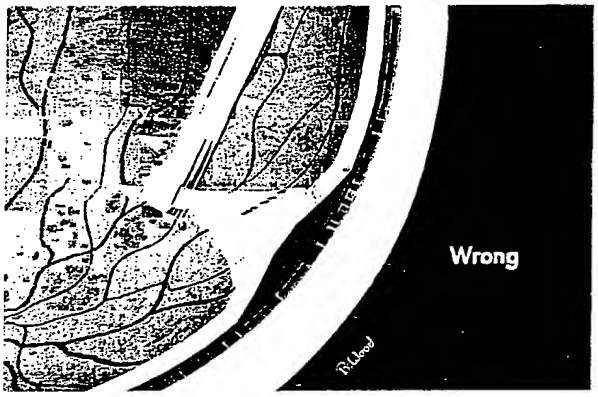

Fig. 127-7 Moving the cutter away from the tissue to be cut adds traction force to the suction-induced force.

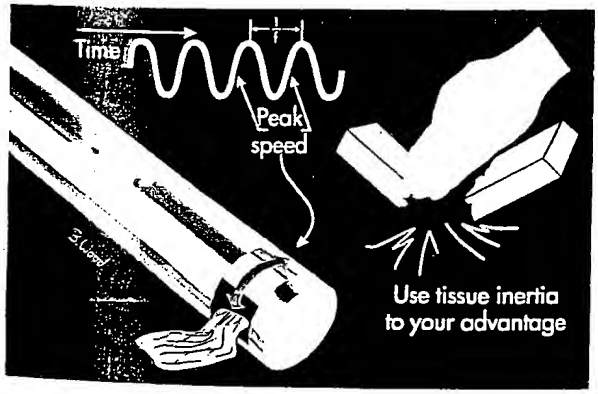

Fig. 127-8 High-frequency cutting reduces vitreous fiber travel, and high-velocity cutting uses tissue inertia for cleaner cutting and less traction.

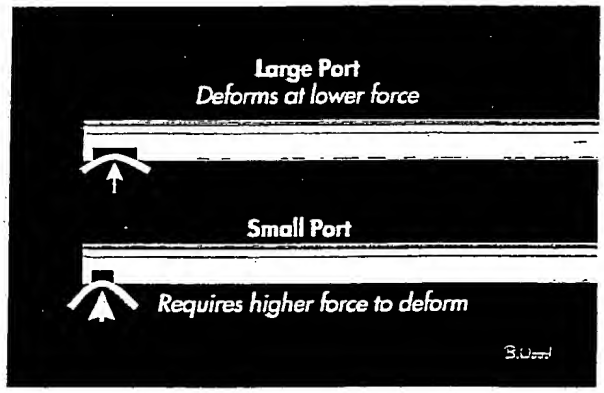

Fig. 127-9 Small ports require higher suction force to deform tissue into cutter.

CONTROL SYSTEMS

All analog parameters using surgical force, such as suction, laser power, radiofrequency (RF) power, shearing rate, and injector rate, should be controlled by proportional depression of the surgeon's foot (linear control). Switching of valves, pumps, electronic devices, and lasers should ideally be controlled by a single integrated system, with functions controlled by the surgeon rather than a nurse or technician.

MICROSCOPE REQUIREMENTS

A stereo operating microscope with magnification up to 30× with coaxial illumination is required. The device should have a beam splitter to facilitate television viewing for the operating room team and for recording. Ideally the television system should be high definition (HDTV) and stereoscopic. At least one assistant should share the surgeon's view, preferably with stereopsis, but most current systems ignore this requirement.

The position of the microscope can be controlled by foot switch, voice, or surgeon's head tracking. Voice control is slower, surgeon specific, less precise, and demanding for the surgeon. Power zoom, focus, and XY positioning are required. Head tracking offers the most natural interface.

Physical stability of the microscope and the patient's head is required to preserve the dimensional stability of the surgical view for microsurgery. Current ceiling-mounted microscopes are worse than floor-mounted microscopes. Operating tables are significantly unstable when contacted by the other members of the operating room team. A stable wrist rest is required for the surgeon, and creating a moat around the patient's head traps effluent fluids and inadvertently dropped surgical tools. The goal is to provide a stable dimensional relationship among the microscope, the patient's head, and the floor systems.[24,70]

Preferably, all power sources for surgical tools should be combined into one physical system for better access to the surgical field. New systems (e.g., Alcon Accurus) have unified controls combining all surgical functions into an integrated system.

HANDPIECE CONSIDERATIONS

All surgical tools should be as light as possible and should be held in the surgeon's fingertips. They should be contoured rather than cylindrical to reduce the force required to prevent dropping. They should be no longer than the distance from the fingertips to the point of contact with the hand. Shorter handles reduce the torque produced by the weight and also reduce friction as the cables, fibers, and tubing used to connect surgical tools slide on the drape. Minimizing the forces required to hold tools increases the surgeon's proprioceptive sense (Weber-Fechner law) and decreases fatigue and tremor.

SCENARIOS

Conjunctival Incisions

Because vitrectomy for most vitreoretinal surgery requires a three-port approach, two conjunctival incisions are required. The temporal incision, for the infusion cannula and primary active tools, should be 60 degrees in extent, centered at the lateral rectus, and 1 to 2 mm from the limbus. Limbal incisions cause bleeding under the surgical contact lens and result in a postoperative ridge, making the fitting of a soft contact lens difficult. A superonasal incision, 1 mm from the limbus and 30 degrees in extent, is used for the endoilluminator and secondary active instruments exchanged from the superotemporal incision.

Traction sutures are unnecessary and disadvantageous for vitrectomy. They are required only if scleral buckling is planned. If scleral buckling is anticipated, the muscles should be trapped with a chamfered hole, fenestrated, short-handled muscle hook and 2-0 silk (not 4-0) suture, which are used to facilitate the assistant's grip and reduce trauma to the muscles (Fig. 127-10).

Sclerotomies

An assortment of same-diameter (20 gauge, 0.89 mm, 0.033 inch) tools has become a de facto standard and is strongly recommended. All current cannula systems are larger than 20 gauge, leak without a plug, and prohibit passage of some essential, axially asymmetric tools.[69]

The wounds should be linear, 1.4 mm long, and parallel to the limbus. A lancet-tipped (symmetric) blade controls size and position better than asymmetric blades for the sclerotomies. Disposable blades or extremely hard materials are required to maintain an extremely sharp tip for penetration of the choroid and nonpigmented ciliary epithelium. Incisions parallel to the limbus prevent inadvertent anteroposterior enlargement of the sclerotomy. A 1.4 mm linear incision rounds out to the 0.89 mm round hole, which should be the size of the blade shank. No plugs, stilettos, 20 gauge needles, transilluminators, or the like are required. The infusion cannula incision should be made first just below the 3 or 9 o'clock position inferotemporally with a 20 gauge lancet blade passed toward the center of the eye but just deep enough to ensure that the widest portion of the blade and the first round section are past the nonpigmented ciliary epithelium. The incision should be made 4 mm posterior to the limbus in adult eyes, or 3 mm if the lens has been removed in a prior operation or if a lensectomy is to be performed. The edge of the sclerotomy can then be grasped with 0.1 mm forceps to fixate the eye while the infusion cannula retention suture is passed. The suture passes should be parallel to the limbus, short, deep, and spaced to accommodate the base of the infusion cannula. The cannula is twisted into position in an oscillatory fashion to ensure passage through the ciliary epithelium, and the suture is tied down. The cannula tip is then inspected with the operating microscope to prevent inadvertent suprachoroidal or

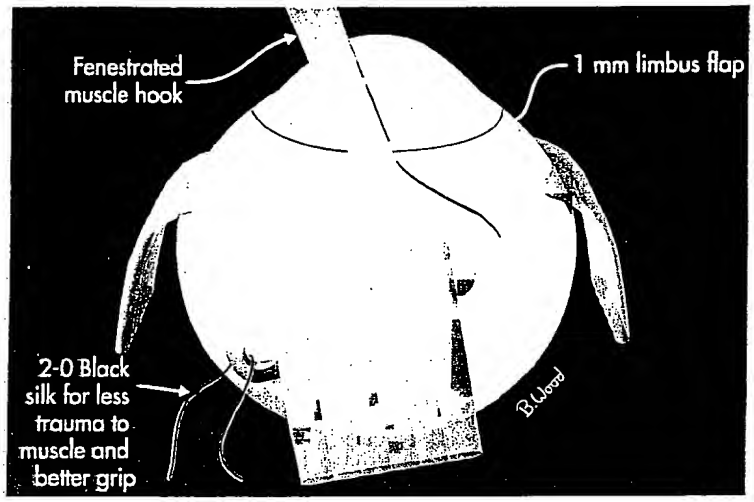

Fig. 127-10 Fenestrated muscle hooks permit safe retromuscle traction suture placement.

subretinal infusion. If tissue is seen over the cannula, it is incised with a 20 gauge lancet blade from the nasal sclerotomy site if the lens has been removed or is to be removed (Fig. 127-11). If the eye is to remain phakic, the microvitreoretinal blade is used to incise the tissue over the cannula from the superotemporal approach, or a 20 gauge needle with a saline-filled syringe is used through the sclerotomy site to increase the intraocular pressure and force the choroid over the needle. If it is anticipated that the infusion will not be seen because of anterior opacities, a 20 gauge, 30 degree bent infusion cannula should be passed deeply into the eye and used for infusion until visualization of the pars plana is possible (Fig. 127-12). At that time, a standard sew-on infusion cannula can be placed in the usual fashion. Alternatively, the cannula can be placed at the beginning of the case but not used until it can be visualized.

The second sclerotomy should be made superonasally just above the 180 degree line, 3 to 4 mm from the limbus, and parallel to the limbus. The endoilluminator tool and associated subsystems should be passed through this opening to stabilize the eye while a third sclerotomy is being made superotemporally. Scleral plugs are not required or useful at this time.

The third incision should be just above the 180 degree line, parallel to the limbus, 20 gauge, and 3 to 4 mm from the limbus. More anterior or nonstandard locations are required in cases of congenital or pathologic abnormalities of the pars plana region or in smaller eyes.

Vitreous Removal

Previous algorithms have stressed removal of axial opacities (core vitrectomy) followed by truncation of the PVC. Cutting technology has improved to the point that one algorithm no longer suffices; therefore each algorithm should be se-

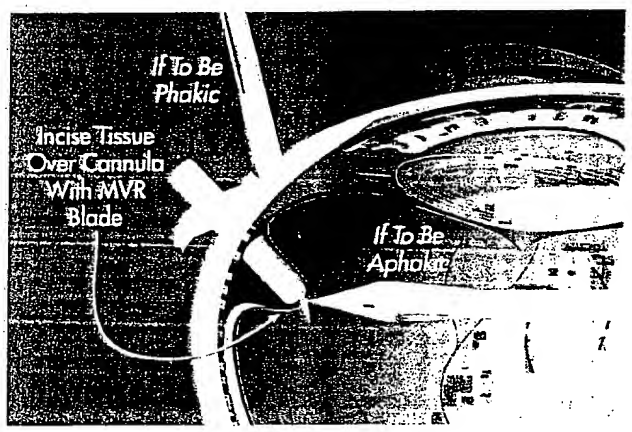

Fig. 127-11 Tissue over the cannula tip can be incised with an MVR blade.

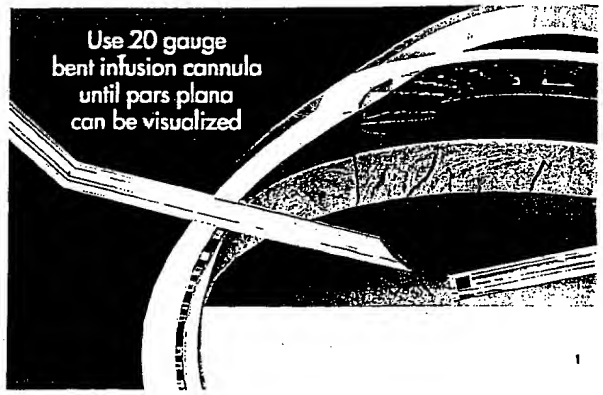

Fig. 127-12 Hyphema, dense cataract, or pupillary membrane must be managed with a hand-held 20 gauge infusion cannula until the pars plana can be visualized for sew-on cannula placement.

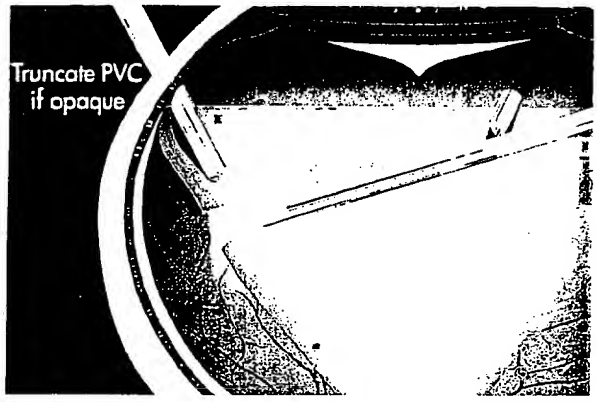

Fig. 127-13 The posterior vitreous cortex *(PVC)* should be entered away from the macula and periphery in an area known to be attached or away from the retina. This incision should be extended circumferentially to accomplish truncation.

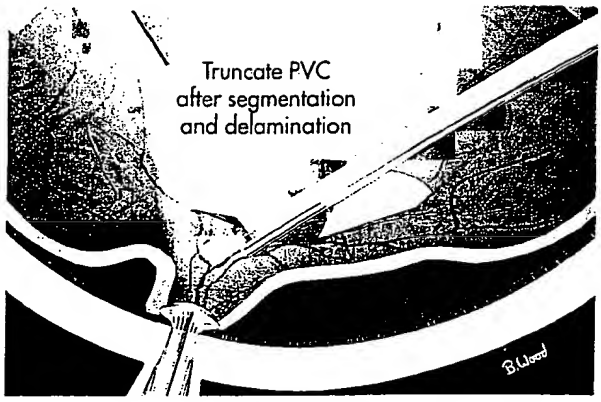

Fig. 127-16 Use of the vitreous cutter to remove the delaminated posterior vitreous cortex–epiretinal membrane complex in a single process. Circumferential 360 degree extension eliminates all anteroposterior traction.

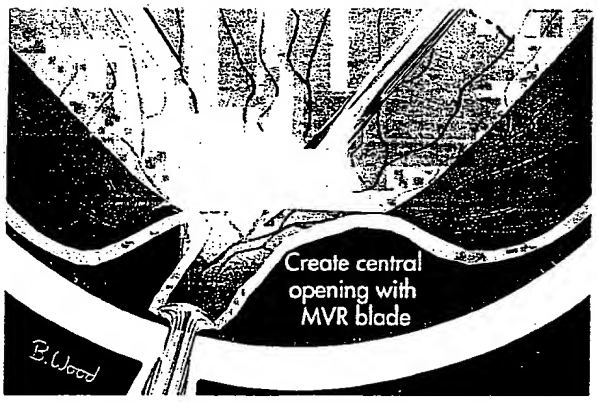

Fig. 127-14 A central edge created by an MVR blade for segmentation/delamination access is preferable to seeking an outside edge.

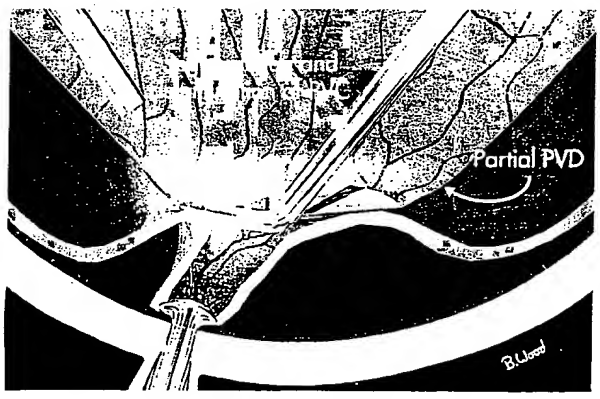

Fig. 127-15 Some initial segmentation can facilitate the preferred inside-out delamination approach. Bimanual dissection and viscodissection should be avoided.

lected according to the specific pathoanatomy of the case. If the AVC is semi-opaque, opaque, or taut, it should be removed first. If it is clear and the lens is to be left in place, it should be retained unless there is an element of anterior loop traction (ALT) (anterior proliferative vitreoretinopathy) or compartmentalization requiring removal (see the next section in this chapter). In the majority of cases, the "core" vitreous requires no specific attention, and the surgeon should proceed in the algorithm to the decision about whether to truncate the PVC or to peel or delaminate the ERM first. If the PVC is opaque or semi-opaque, it usually requires truncation before the ERM can be peeled or delaminated (Fig. 127-13). When there is a partial posterior vitreous detachment (PVD) and the ERM is continuous with sections of the PVC, delamination should precede PVC truncation (Figs. 127-14 to 127-16).

If sub-PVC blood products are encountered while PVC truncation is under way, straight end-opening cannula suction should be used (vacuum cleaning or extrusion)[20,68] (Figs. 127-17 and 127-18). If, in the process of PVC truncation, elements of PVC are stretched between areas of ERM, they can be resected with the cutter only if it can be done without undue traction on the retina (Fig. 127-19). Scissors should be used if these sections of the PVC are taut.

Anterior loop traction is a significant feature of anterior proliferative vitreoretinopathy (PVR), retinopathy of prematurity (ROP), some traumas, anterior hyaloidal fibrovascular proliferation (retrolenticular neovascularization), and proliferative diabetic retinopathy (PDR). These cortical fibers are made taut by hypocellular gel contraction extending in the anteroposterior direction from the vitreous base to the pars plana, the ciliary body, and even the posterior iris surface. They can be present from a few degrees up to 360 degrees. ALT must be carefully differentiated from the "skirt" that is left after AVC or PVC truncation, the vitreous base, the vit-

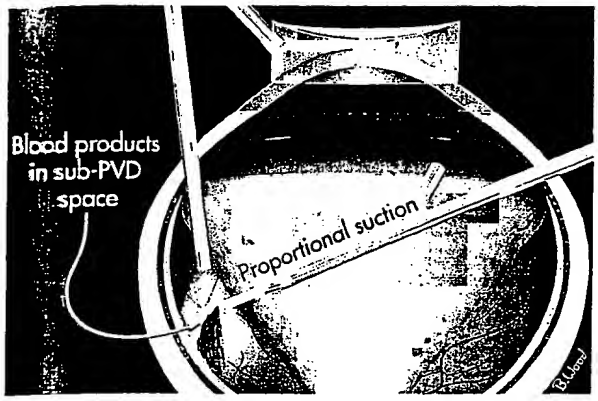

Fig. 127-17 Low, proportional suction, rather than a flute needle or cutter, permits safe, nonpulsatile removal of sub–posterior vitreous cortex blood products.

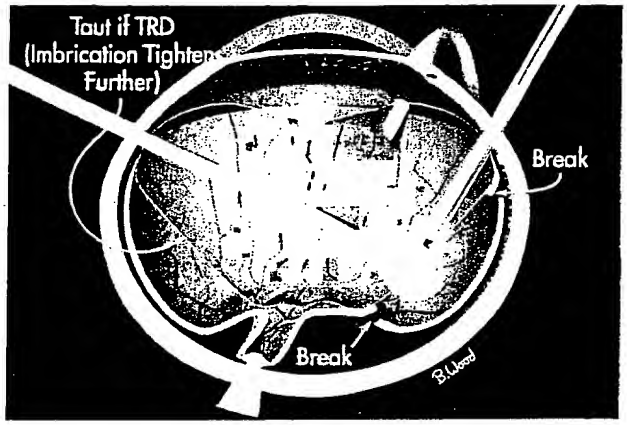

Fig. 127-19 Resection of the posterior vitreous cortex with a vitreous cutter can cause undue traction on the retina.

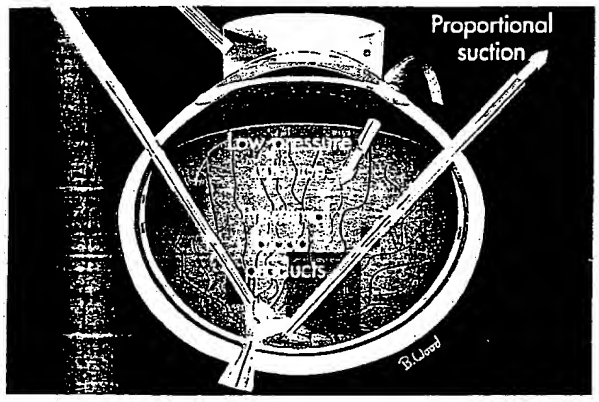

Fig. 127-18 Safe, proportional foot-controlled suction (30 mm Hg) readily removes preretinal blood products without retinal damage.

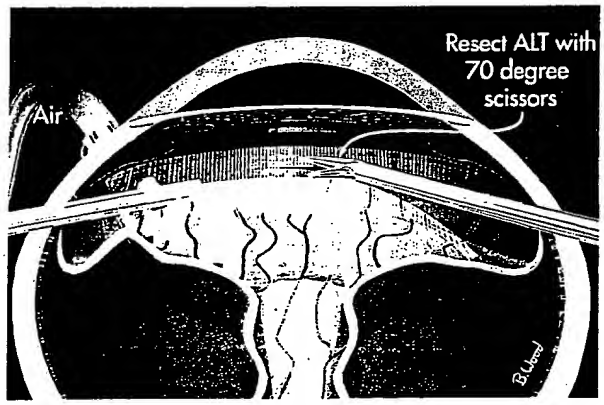

Fig. 127-20 Broad anterior loop traction *(ALT)* can be resected with a vitreous cutter. Narrow or taut ALT should be resected with scissors.

reoretinal interface zone, or frontal plane AVC or PVC traction. ALT is best visualized with scleral depression by the assistant. Although wide-angle viewing systems exist that facilitate a view of the periphery, scleral depression tends to loosen the ALT and change the contour. If ALT is broad, it can be resected with a vitreous cutter. If it is narrow or especially taut, it should be resected in a circumferential manner with scissors (Fig. 127-20).

LENS MANAGEMENT AND COMPARTMENTALIZATION

In addition to its normal optical function for the patient, the lens affects the management of retinal detachment by vitrectomy. Cells, as well as cytokines, proteins, and inflammatory components, are retained in the vitreous cavity and thus are exposed to the retina longer in the phakic eye. In the cases of PVR, giant breaks, uveitis, and severe trauma, it usually is advantageous to remove the lens to accomplish decompartmentalization of the eye.[10,33,36-40,74,80] This also permits better dissection of the ALT, eliminates concern about subsequent cataract surgery, and facilitates dissection under air. In PDR there is a trade-off in that the presence of the lens greatly reduces neovascular glaucoma but allows anterior fibrovascular proliferation (retrolenticular neovascularization), greatly prolongs the retention time of postoperative hemorrhages, and frequently necessitates subsequent cataract surgery in high-risk patients. Lens removal in conjunction with diabetic vitrectomy can be managed with pars plana lensectomy, retention of the anterior lens capsule, and introduction of a posterior chamber lens in front of the capsule.

Endocapsular lensectomy is the most efficient and safe method of lens removal. The first step is placement and verification of the infusion cannula. To prevent traction on the retina, anterior vitrectomy should be performed before lensectomy. The cutter should then be used to make a circular rhexis

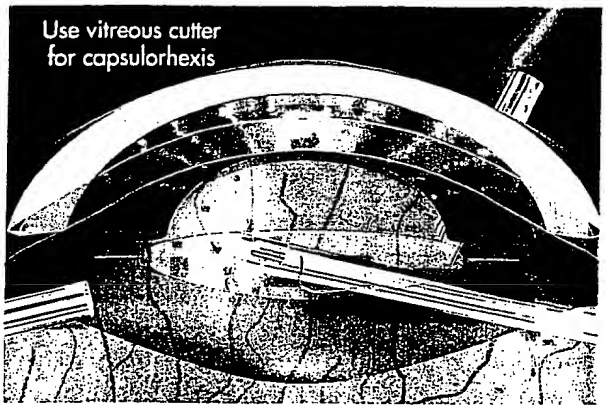

Fig. 127-21 After an anterior vitrectomy is performed, a vitreous cutter is used to create a circular posterior capsulorhexis.

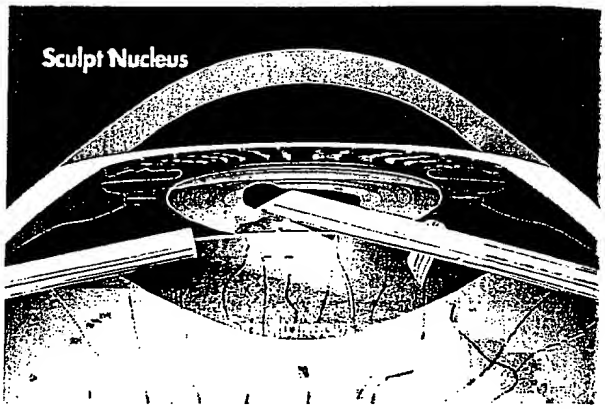

Fig. 127-23 Simultaneous sonification and aspiration with the 20 gauge fragmenter at moderate power is used to sculpt the epinucleus, nucleus, and inner cortex.

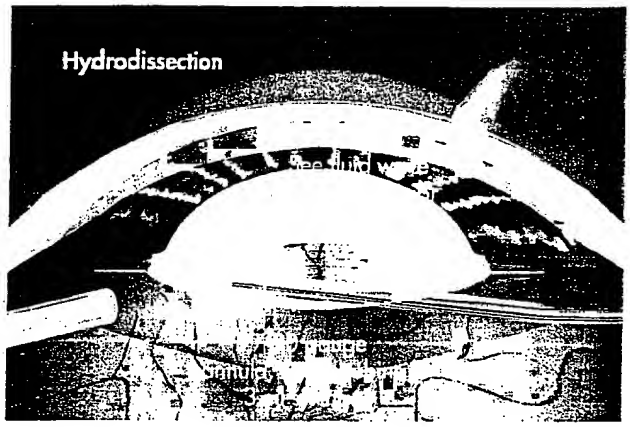

Fig. 127-22 A fluid wave should be seen beneath the anterior capsule during hydrodissection and delineation.

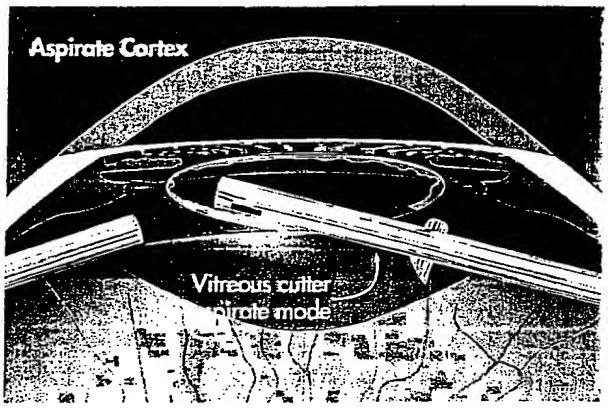

Fig. 127-24 Use the vitreous cutter in suction-only mode to aspirate the cortex; then switch to cutting mode after the cortex has been displaced from the capsule.

in the posterior capsule (Fig. 127-21). Hydrodissection and delineation should be performed with a 27 to 30 gauge blunt cannula. A fluid wave should be seen under the anterior lens capsule (Fig. 127-22). An assistant-held syringe or a foot pedal–controlled fluid injector connected to a short length of tubing facilitates this step. Sculpting of the epinucleus, nucleus, and inner cortex with the fragmenter at moderate power levels is the next step (Fig. 127-23). Simultaneous sonification and suction using a 20 gauge tool (fragmenter) is safer and better than intermittent suction followed by sonification without aspiration. The cortex should then be aspirated with the vitreous cutter in the suction-only mode (Fig. 127-24). The cutter can then be used in the cutting mode after the cortex has been displaced from the capsule. If severe miosis occurs, scleral depression or injection of 1:10,000 epinephrine facilitates the required removal of all peripheral cortex. Proportional (linear) suction should be used, with typical suction levels of 100 to 150 mm Hg, in the capsular bag.[16] A capsulotomy to facilitate forceps removal of the capsule should be made with the MVR blade after all cortex is removed, if lens implantation is not planned. The majority of the capsule should then be removed with the end-opening, diamond-coated forceps, using a circular, zonular rhexis motion. Removal of all capsule prevents the inflammation and peripheral proliferation associated with the retention of lens material and fibrosis of peripheral iridectomies.

Intraocular lenses should be removed for severe uveitis, anterior vitreous cortex fibrovascular proliferation, and many fibrin syndrome cases. Removal should be accomplished by making a posterior shelving, limbal incision with a sharp blade, and completing the dissection with scissors for 100 to 160 degrees. Injecting viscoelastics into the anterior cham-

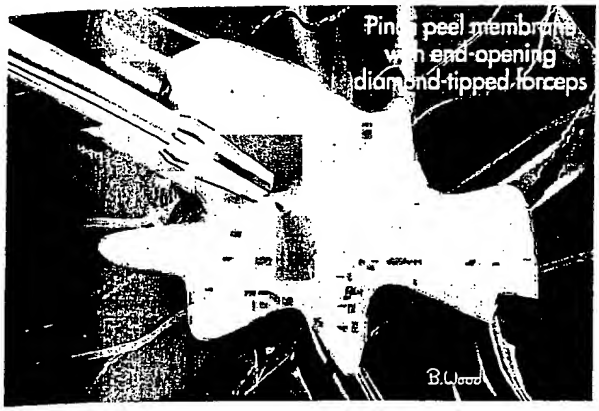

Fig. 127-25 Forceps membrane peeling reduces retinal damage and can be used on early, less adherent starfolds.

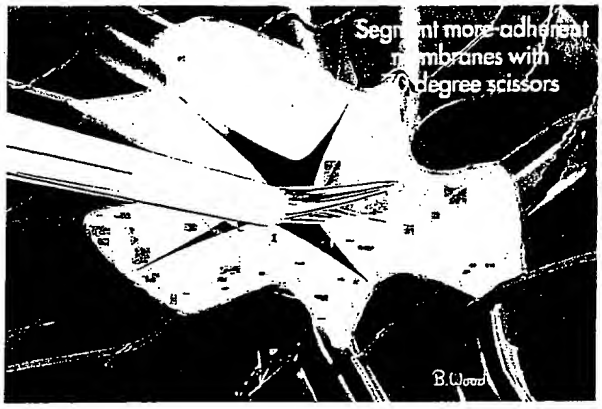

Fig. 127-26 Inside-out segmentation and delamination is required for later, denser, and more adherent membranes.

ber should be avoided if silicone oil might be used, since viscoelastics facilitate emulsification of oil. It is important not to distort or damage the cornea so as to have excellent visualization later in the procedure. Anterior chamber lenses are easily removed by depressing the scleral edge at the site of the haptic. Fortunately, iris plane lenses are uncommon today. They frequently require scissors sectioning of the haptics and iris sutures for safe removal. Most posterior chamber lenses can be removed by gentle rotation and haptic depression, but some require sectioning of the haptics to avoid traction on the ciliary body and resultant bleeding. The wound should be closed with multiple X-type 9-0 monofilament sutures to prevent wound leaks and intraoperative astigmatism. Residual capsule, cortex, and associated fibrous proliferation should be completely removed (as described earlier) to reduce inflammation and peripheral proliferation.

EPIRETINAL MEMBRANE MANAGEMENT

The decision node in ERM management has three branches. The ERM can be removed by elongation (peeling), segmentation, or delamination (inclusive shear). The membrane can be segmented to release tangential forces and the epicenters retained. Choices are somewhat disease dependent in that PDR usually, and ROP always, requires delamination. PVR requires peeling in most early, less adherent cases, with segmentation or delamination used in later, denser, and more adherent cases (Figs. 127-25 and 127-26).*

The central biologic issue is to minimize trauma to the internal limiting lamina (ILL) (Figs. 127-27 to 127-29), eliminate all tangential force from the retina, and reduce reproliferation from bleeding and retained ERM. The problem of damage to the ILL can be reduced by better inclusive shears.

*References 18, 19, 26, 32, 59, 76, 78.

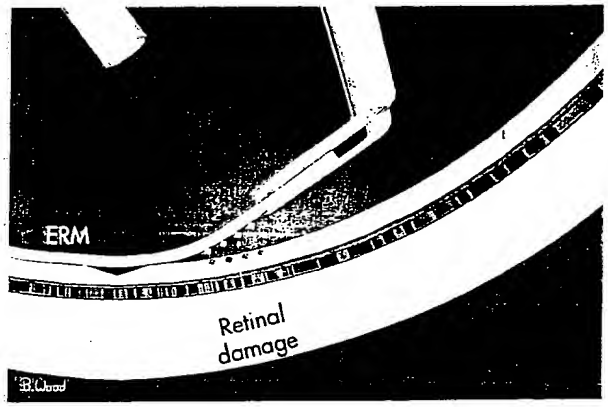

Fig. 127-27 Bent needles, picks, side-opening forceps, and viscodissection damage the retina, leading to increased reproliferation. *ERM*, Epiretinal membrane.

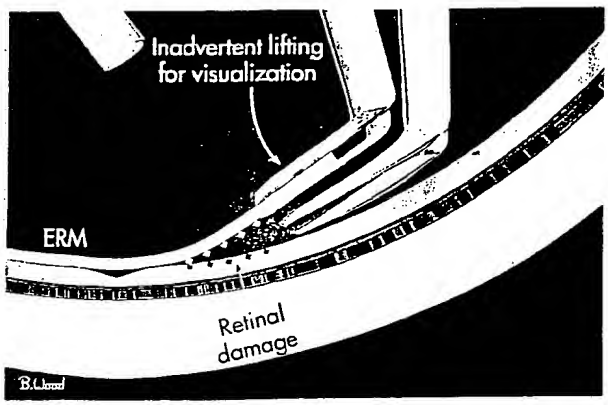

Fig. 127-28 The desire to view the dissection by lifting the epiretinal membrane *(ERM)* during delamination causes unnecessary retinal traction and damage.

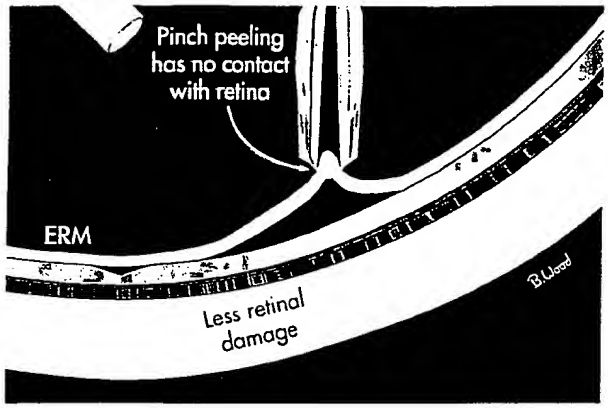

Fig. 127-29 End-opening forceps peeling without retinal contact causes less damage to the retina, thereby reducing reproliferation.

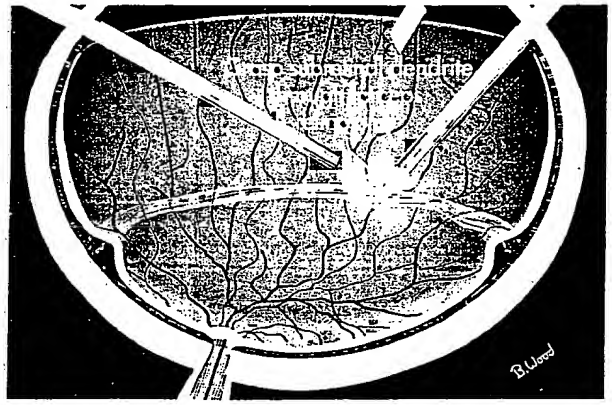

Fig. 127-30 If the retina cannot be reattached without an undistorted macula, forceps of varying angles can be passed through an existing break or linear retinotomy to remove subretina proliferation.

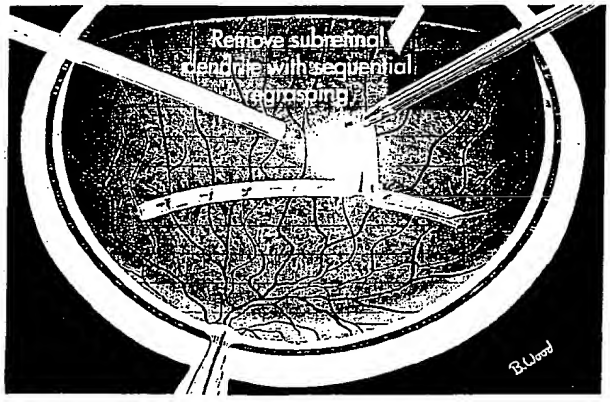

Fig. 127-31 Long subretinal dendrites can be removed by using a sequential regrasping technique.

MANAGEMENT OF SUBRETINAL PROLIFERATION

Subretinal proliferation can be placoid, dendritic, or annular in configuration. Because the biologic behavior of subretinal proliferation seems to be unlikely to result in reproliferation, subretinal membrane removal is dictated by geometric considerations. If the retina cannot be reattached with an undistorted macula without removal of subretinal membrane, subretinal surgery is indicated.

Subretinal surgery can be divided into elongation (peeling) and inclusive shearing (segmentation, scissors). If a retinal break is appropriately positioned, forceps of varying angles can be used to grasp and remove long dendrites with a sequential regrasping technique (Figs. 127-30 and 127-31). If the membrane is placoid, elongation also can be used. At times, dendrites are very adherent or are connected to vascularized areas, and segmentation is more appropriate. Shearing or forceps retinotomy without tissue removal should be used with either method if no appropriate retinal break is present.

NONCUTTING SUCTION TECHNIQUES

Various configurations of tapered or nontapered, curved, straight, or silicone rubber–equipped suction devices can be used to remove material from the eye (vacuum cleaning, extrusion). End-opening. 20 gauge cannulas with low suction levels are used to remove free blood products or small particles of lens material from the retinal surface or from within the eye. Proportional (linear) suction at very low levels (5 to 40 mm Hg) should always be used.

Tapered cannulas that are bent are better than small flexible silicone tubing cannulas and can be used for internal drainage of subretinal fluid. The algorithm for internal drainage of subretinal fluid begins with drainage, which is followed by fluid-air exchange, with continued or repetitive internal drainage of subretinal fluid.

SURFACE (INTERFACIAL) TENSION MANAGEMENT

The air (gas) interface with aqueous (72 dynes/cm^2) provides more surface tension than the silicone-aqueous interface (40 dynes/cm^2). Hyaluronic acid, chondroitin sulfate, and lipoproteins from blood or inflammation lower the interfacial tension of the silicone-aqueous interface to about 30 dynes/cm^2.

Surface tension management is far more significant than buoyancy effects provided by air, gas, or silicone. The purpose of these agents is to eliminate trans–retinal hole fluid flow, thus restoring a transretinal pressure gradient. This effect is best termed *rhegmatogenous confinement.*

Silicones and gases recompartmentalize by sequestering proteins at the retinal surface (Fig. 127-32). These substances increase reproliferation at the interface because of retention of cells and cytokines, and inflammation. The best silicones are those with the highest electrical resistance, low-

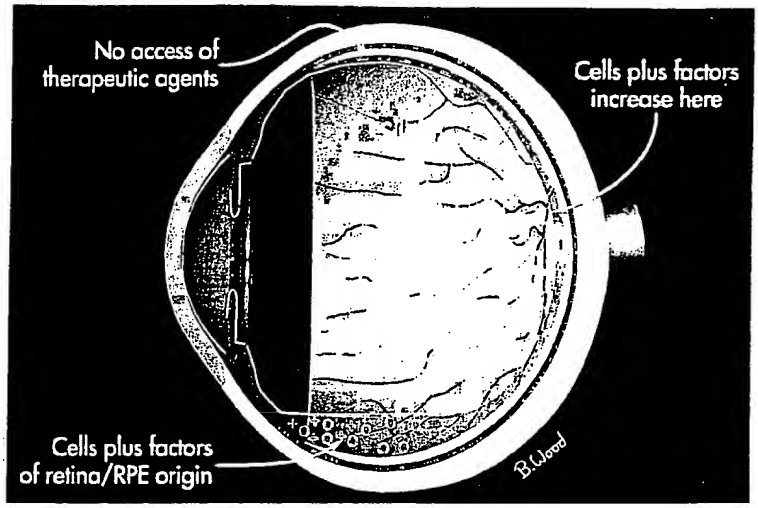

Fig. 127-32 Silicone and gases increase reproliferation by sequestering cells and factors at the retinal surface and decrease access of therapeutic agents to the retina.

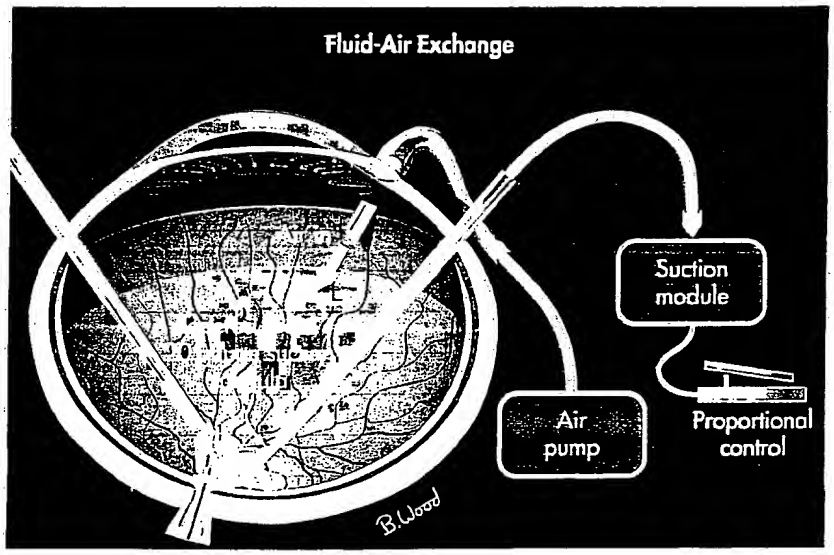

Fig. 127-33 An air pump infuses air through the infusion cannula and maintains intraocular pressure while intraocular and subretinal fluid is removed with a proportional suction cannula.

est vapor pressure, highest viscosity, and highest average molecular weight.

An inferior peripheral iridectomy allows aqueous to enter the anterior chamber from below and, it is hoped, prevent silicone contact with the cornea. Less than 10% of these cases develop corneal problems because of the iridectomy and higher-quality silicone. Subacute angle closure (2%) and emulsification glaucoma are very rare if proper precautions are taken. With the improvements in silicone oil, the incidence of glaucoma is now less than 10%, rather than 15% to 50% as previously reported.[5,8] Through surface tension effects, silicone seals unseen retinal breaks and retinal breaks that occur after surgery. Silicone also is useful for retinopexy avoidance to reduce the reproliferation that is associated with large-area breaks or retinectomies.[14,17,75]

Fluid-Air Exchange

Air, for surface tension management, should be injected through the infusion cannula while intraocular and subretinal fluid is simultaneously removed with noncutting techniques, as described previously (proportional suction and extrusion) (Fig. 127-33). Constant-pressure air pumps control intraocular pressure, are nonpulsatile, and can provide large flow rates to compensate for wound leaks. Incremental retinec-

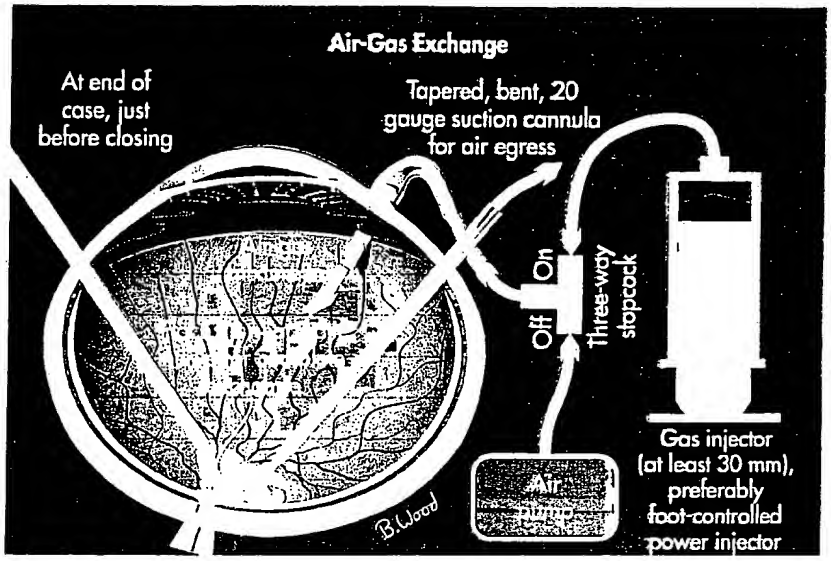

Fig. 127-34 Volumetric gas injection combined with proportional air evacuation allows total air-gas exchange and correct gas concentration.

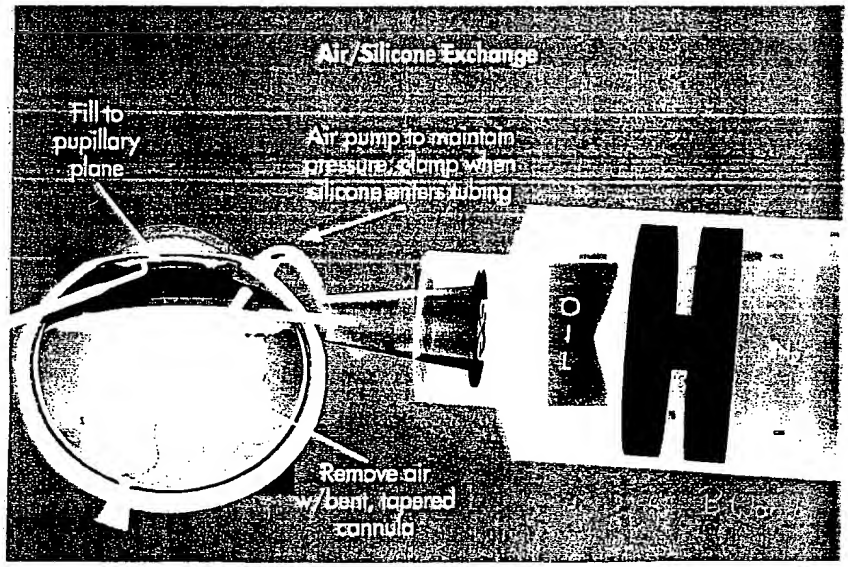

Fig. 127-35 Silicone is injected through a short 16 to 20 gauge cannula. Air is removed via proportional suction cannula until the silicone reaches the pupillary plane.

tomy and further delamination, peeling, or segmentation can be performed under air surface tension management.

Air-Gas Exchange

If a long-acting gas is chosen to maintain surface tension until retinopexy takes effect, it should be injected in the desired final concentration through the infusion cannula after air-fluid exchange. The air is aspirated with constant low suction near the optic nerve to ensure complete exchange and accurate gas concentration (Fig. 127-34). Power volumetric injectors are preferable for this purpose. Injecting aliquots of gas into an air-filled eye provides little control over concentration and subsequent bubble size because of unknown ocular volume.*

Air-Silicone Exchange

Because air has a higher interfacial tension than does silicone, fluid-air exchange with internal drainage of subretinal fluid to reattach the retina should precede silicone infusion. Silicone should be injected with a pressure-controlled power injector through a short, 16 to 20 gauge straight cannula or through the infusion cannula with very short tubing (Fig. 127-35). The

*References 1, 2, 15, 21-23, 25, 26, 29, 34, 35, 44, 49-54, 57, 62, 66, 67.

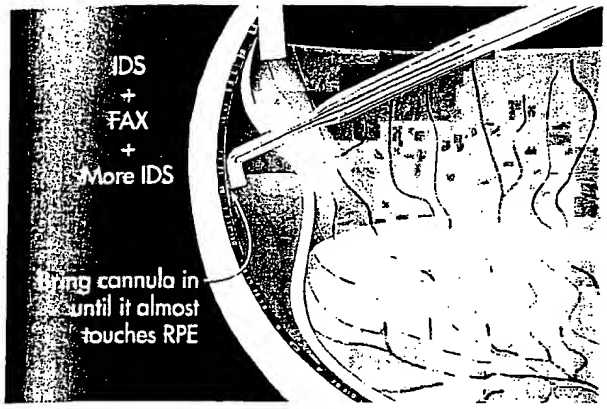

Fig. 127-36 A tapered, bent suction cannula *held near* the retinal pigment epithelium and controlled by proportional suction allows safe internal drainage of subretinal fluid *(IDS). FAX,* Fluid-air exchange.

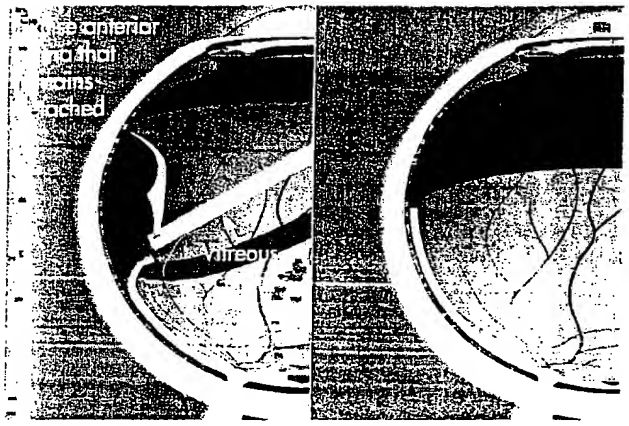

Fig. 127-37 Retinectomy is performed with a vitreous cutter to manage foreshortening or residual traction.

air can be removed by proportional aspiration until the silicone reaches the pupillary plane. Infusion fluid should be used to reform the anterior chamber if it becomes flat. Hyaluronic acid lowers the silicone interfacial tension and should not be used to deepen a flat chamber.

RETINECTOMY

Retinectomy should be performed only after fluid-air exchange and internal drainage of subretinal fluid (SRF) (Fig. 127-36). If subretinal air appears as internal drainage of SRF is slowly proceeding, the subretinal air location indicates retinal traction or retinal foreshortening. Further vitrectomy, delamination, subretinal surgery, retinectomy, or scleral buckling may be required at this point. If this seems unnecessary, retinectomy will be required to manage the foreshortening or residual traction. This should be done incrementally with the vitreous cutter or scissors until the retina is reattached (Fig. 127-37). Retinectomy performed under fluid is difficult and frequently results in excessive retinectomy. Thermal laser retinotomy causes retinal damage, again inciting reproliferation. Large vessels should be pretreated with 1 mHz bipolar RF thermal coagulation. Tacks, retinopexy, and retinoplasty are discussed later.

CONTROL OF BLEEDING

Transient (approximately ± 5 minutes) elevation of IOP, preferably with a servo system, is the best means of controlling intraoperative bleeding. Rapid elevation of IOP when bleeding is noted prevents the formation of extensive, tenacious preretinal blood clots. The IOP can be maintained between capillary and diastolic arterial pressure while vascular epiretinal membrane attachment areas are being dissected. The IOP should be normalized within a few minutes after clotting occurs. The Alcon Accurus system provides foot-controlled elevation of IOP, which is ideal for this technique. Any areas still bleeding should be treated with unimanual, bipolar, 1 mHz endodiathermy (Fig. 127-38). Laser endophotocoagulation is also useful for this purpose, with the choice made by the presence of retinal elevation (Fig. 127-39). Pretreatment of vascular areas with RF or laser results in retinal necrosis, prolongs the procedure, and causes unnecessary coagulation of the tissue to be removed.[43,79]

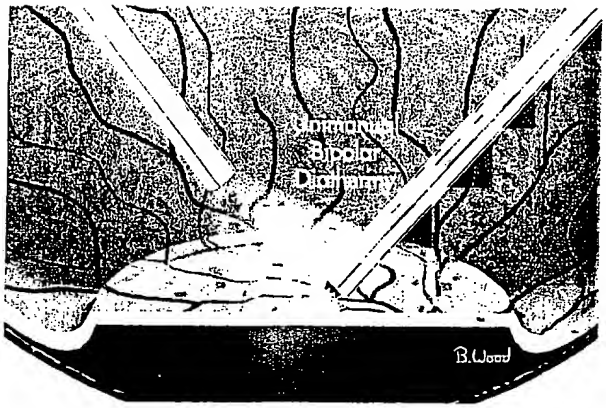

Fig. 127-38 Unimanual bipolar 1 mHz radiofrequency diathermy is used for all elevated bleeders not controlled with transient intraocular pressure elevation.

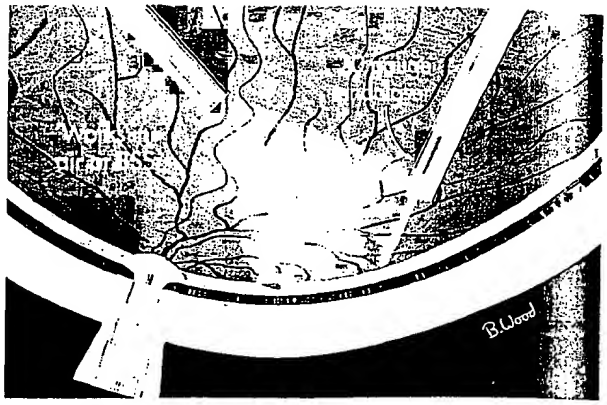

Fig. 127-39 Laser endophotocoagulation (argon, krypton, or diode) under fluid or air is used for flat focal bleeders.

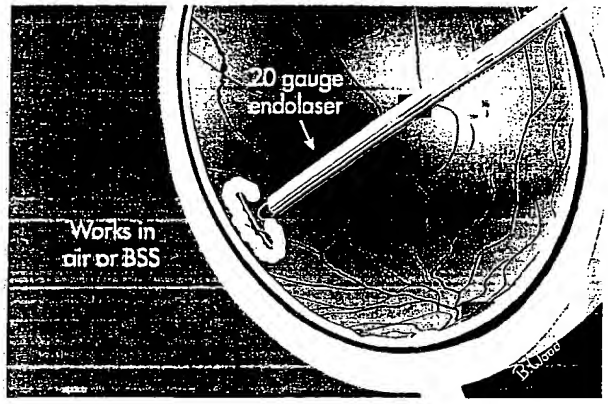

Fig. 127-40 Laser endophotocoagulation "painting" results in less tissue destruction, more uniform retinopexy, and stronger tensile strength of the retinal-RPE adherence.

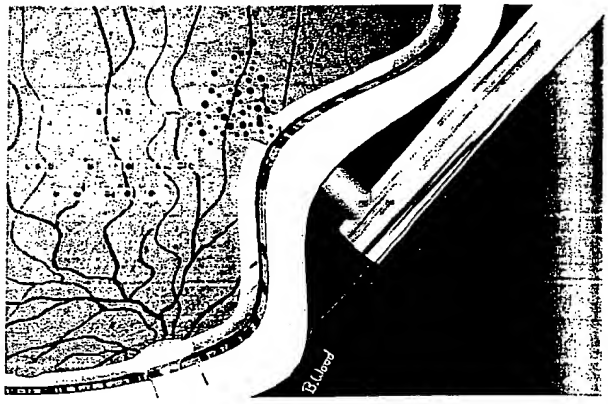

Fig. 127-41 Cryopexy causes inflammation and dispersion of viable RPE cells, leading to increased proliferation.

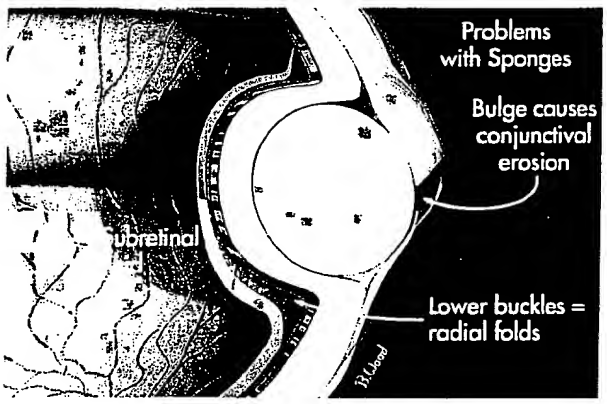

Fig. 127-42 Sponges create subconjunctival bulging, erosion of the conjunctiva, and an irregular buckle contour with retinal folds and subretinal fluid leakage.

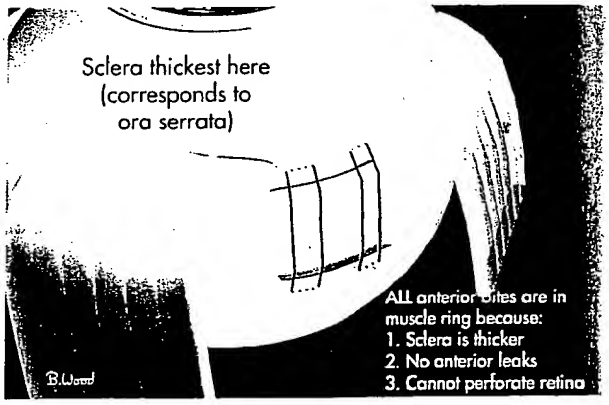

Fig. 127-43 Silicone exoplants 6 to 9 mm wide are used for most scleral buckling. Anterior suture bites into the muscle ring reduce retinal perforation.

PERMANENT RETINAL-RPE ADHERENCE

Retinopexy (cryopexy, RF, laser), tacks, incarceration, suturing, and retinoplasty (glue) all have been used to create permanent retinal-RPE adherence. Suturing and incarceration create too much distortion, bleeding, and reproliferation from tissue damage. Tacks are no longer used because they cause distortion, pull through the retina as reproliferation occurs, damage all layers, leading to scarring (retina, RPE, choroid, and sclera), cause bleeding, and occasionally dislocate.

All forms of retinopexy create tissue destruction and reproliferation and should be used as little as possible. Continuous (painting) laser endophotocoagulation is preferable to intermittent circular retinopexy lesions because of more uniform tissue destruction and resultant tensile strength (Fig. 127-40). Panretinal photocoagulation should be used only for vasoproliferative retinopathies, not for PVR. Cryopexy probably causes more proliferation than laser or diathermy and should be avoided in vitrectomy surgery (Fig. 127-41).

Retinoplasty would prevent the need for tissue-destructive retinopexy, tacks,[27] gas, and silicone. A bio-safe retinoplasty substance should greatly reduce the monumental problem of reproliferation resulting from surgical intervention. The ideal substance would be bio-safe (e.g., paint-on ILL-retina polymer). This would reduce cellular migration, restore the transretinal pressure gradient, reduce bleeding, and have elasticity greater than or equal to that of the retina. Cyanoacrylate is difficult to use; the monomer is carcinogenic and mildly exothermic and is excessively rigid.[42,63,64,73] The goal is restoration of retinal continuity—hence the term *retinoplasty*—rather than creation of retinal-RPE adherence—that is, *retinopexy*.*

PANRETINAL PHOTOCOAGULATION

Panretinal photocoagulation (PRP) reduces the production of vascular endothelial growth factor (VEGF), causes the RPE to release an inhibitory substance (TGF-β), and increases choroidal oxygen transport to the retina.[4,71] Argon, krypton, or, preferably, diode-pumped, frequency-doubled YAG (532 nm) lasers can be used.

SCLERAL BUCKLING FOR VITREORETINAL SURGERY

Silicone exoplants with horizontal mattress, 5-0 monofilament nylon sutures with limbus-parallel scleral bites are recommended for vitreoretinal surgery. Sponges create subconjunctival bulging, with subsequent dellen formation and extrusion (Fig. 127-42). For this reason and because of interstitial spaces, they more frequently result in infection. Sponges and other elastic buckles create an irregular buckle contour with resultant retinal folds and SRF leakage.[41,65,72]

Segmental, circumferential buckles using segments of 6 to 9 mm wide, nongrooved silicone exoplants are ideal for virtually all situations (Fig. 127-43). I never use radial buckles. The same material with butt-joined 5-0 nylon sutures is recommended for encircling tires for PVR and giant breaks (Fig. 127-44).

*References 3, 6, 7, 28-32,45, 67, 68, 77.

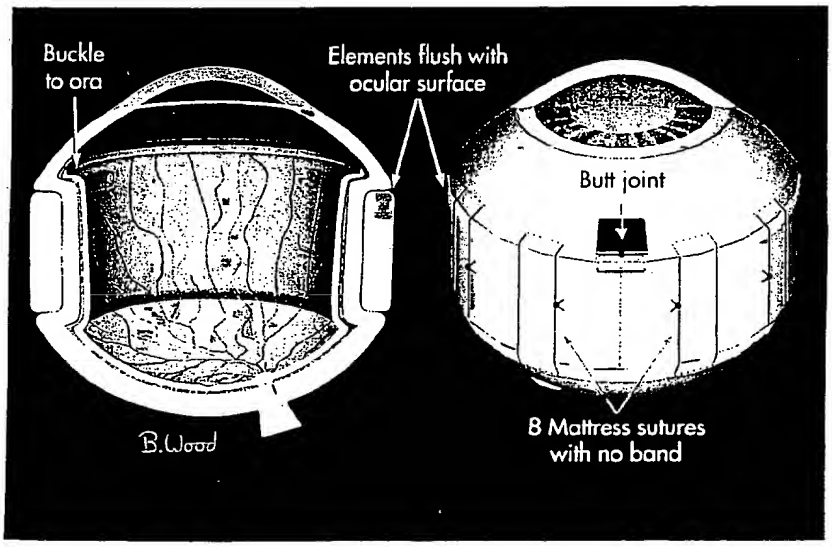

Fig. 127-44 Encircling tires (6 to 9 mm wide, silicone) butt-jointed with 5-0 nylon sutures and no band are used for PVR and giant breaks.

SCLEROTOMY SUTURES

Monofilament 8-0 nylon sutures offer the best compromise between tensile strength and leakage caused by larger needle diameters. Monofilament nylon or equivalent sutures are elastic and close wounds that have opened as a result of undue pressure on the globe. Inelastic sutures, such as silk, should not be used. Absorbable sutures cause wound leaks and inflammation from the absorption process. A running shoelace suture with three to five bites for a typical 1.4 mm, 20 gauge sclerotomy is fast and easy and offers tight wound closure.

CONJUNCTIVAL CLOSURE

Running 6-0 plain gut sutures for the 1 mm limbus-based flap closure eliminates postoperative conjunctival foreshortening and redundancy. Suturing of Tenon's capsule to the muscle insertion causes ptosis, limitation of ocular motility, and inadvertent conjunctival incisions during reoperation.

SUBCONJUNCTIVAL PHARMACOTHERAPEUTICS

Subconjunctival antimicrobials for gram-negative and gram-positive bacteria and penicillinase-producing *Staphylococcus* organisms should be used after all vitrectomies. A subconjunctival steroid injection should be given in all cases unless the patient is known to have corticosteroid-induced glaucoma or has immune deficiency.

SURGICAL ALGORITHMS

Earlier portions of this chapter provided an intellectual framework of physical, biologic, and surgical principles. Each of the surgical scenarios has been illustrated and described. The combination of these scenarios into a surgical algorithm is disease-state dependent, and indications and specific management of disease states are left to other chapters. Algorithms for each common disease state follow (Fig. 127-45).

SUMMARY

Conservative indications, aggressive use of the best techniques and technologies, and careful follow-up are required to achieve optimal results in vitreoretinal surgery. Continued improvements in instrumentation and biotherapeutics are needed for vitreoretinal surgeons to achieve better results in managing the diseases that have such high recurrence rates and such tragic outcomes.

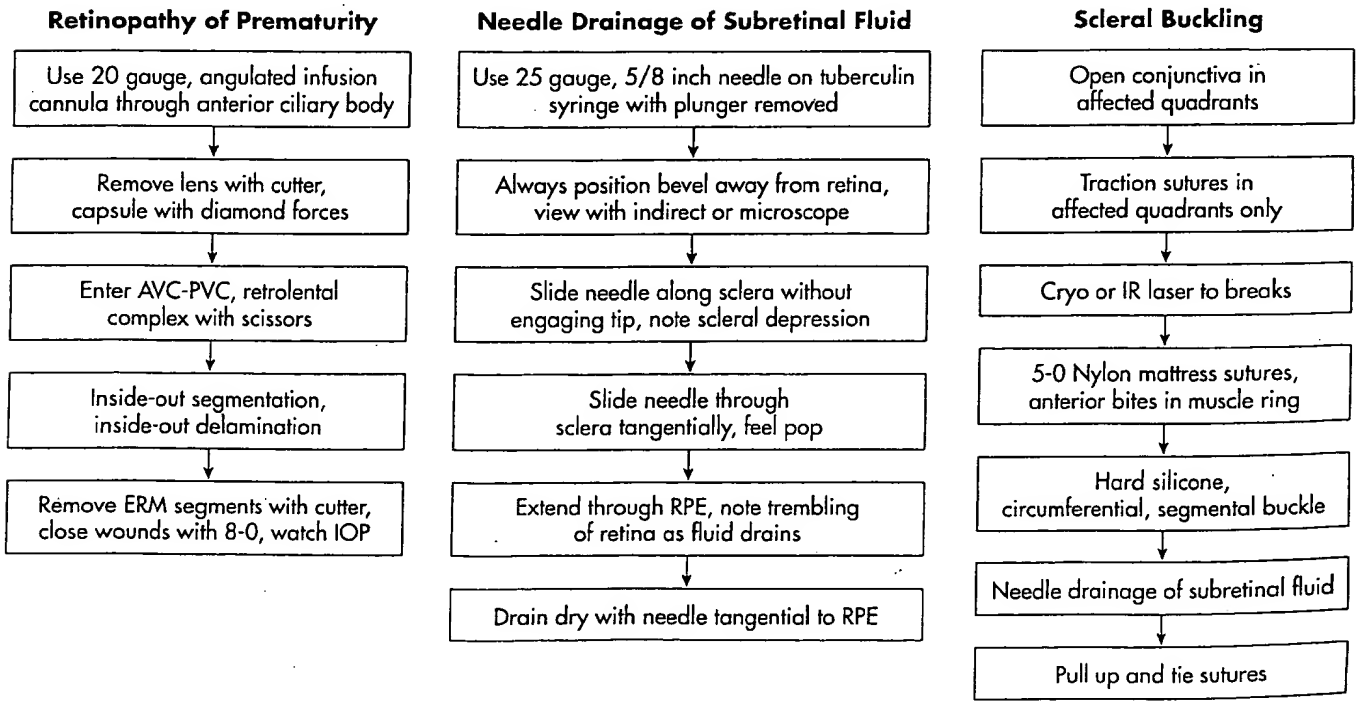

Fig. 127-45 Algorithms for common vitreoretinal disease states.

Fluid Air-Gas Exchange

- Topical anesthesia
- Betadine drops
- Sterile speculum
- Patient lying on side
- Inject gas-air with needle 2 mm into eye at highest point of eye
- Fluid egress at lowest point with 25 gauge needle 2 mm into eye

Pneumatic Retinopexy

- Topical anesthesia
- Betadine drops
- Sterile speculum
- Patient lying on side
- Inject with needle 2 mm into eye at highest point of eye
- Paracentesis at slit lamp
- Laser break(s) when attached

Retinal Detachment

- Core vitrectomy
- Visualization options include scleral depression, wide-angle contact + inverter, and endoscope
- Remove posterior flap of horseshoe tears and all identifiable traction on retinal breaks
- Internal drain of SRF with tapered, angled cannula and proportional suction
- Fluid-air exchange while continuing IDS
- Confluent endophotocoagulation around breaks
- Air-gas exchange with 16% C3F8 or 25% SF6

Endophthalmitis

- Suture cataract wound to prevent leaks
- Make MVR incision and suture infusion cannula in place
- Do not turn on infusion until cannula seen
- Make PI with cutter from posterior to remove fibrin from anterior surface of IOL
- Connect syringe to aspiration line near cutter and collect 1-3 ml for blood culture bottles
- Core vitrectomy, avoid traction on retina
- Inject vancomycin 1.0 and ceftazidime 0.25

Dropped Lens Material

- Remove all vitreous using cutter, endoilluminator, and contact lens before removing any lens material
- High CPM, do not pull back while cutting, use low suction
- Pick up lens material with fragmenter and proportional suction
- Activate US to fragment piece
- Use two-handed technique
- Repeat until lens material gone

Fig. 127-45—cont'd Algorithms for common vitreoretinal disease states.

Continued

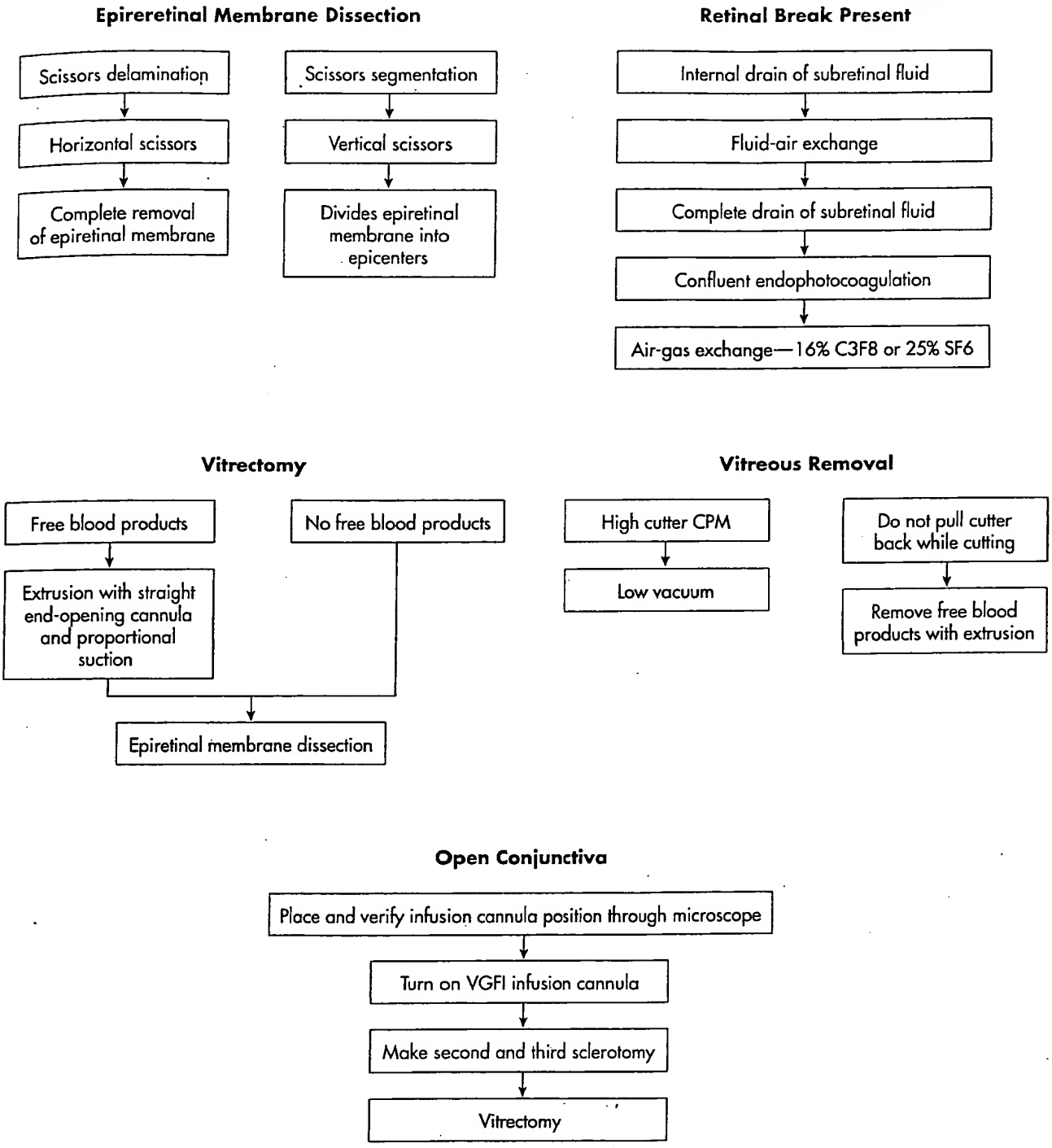

Fig. 127-45—cont'd Algorithms for common vitreoretinal disease states.

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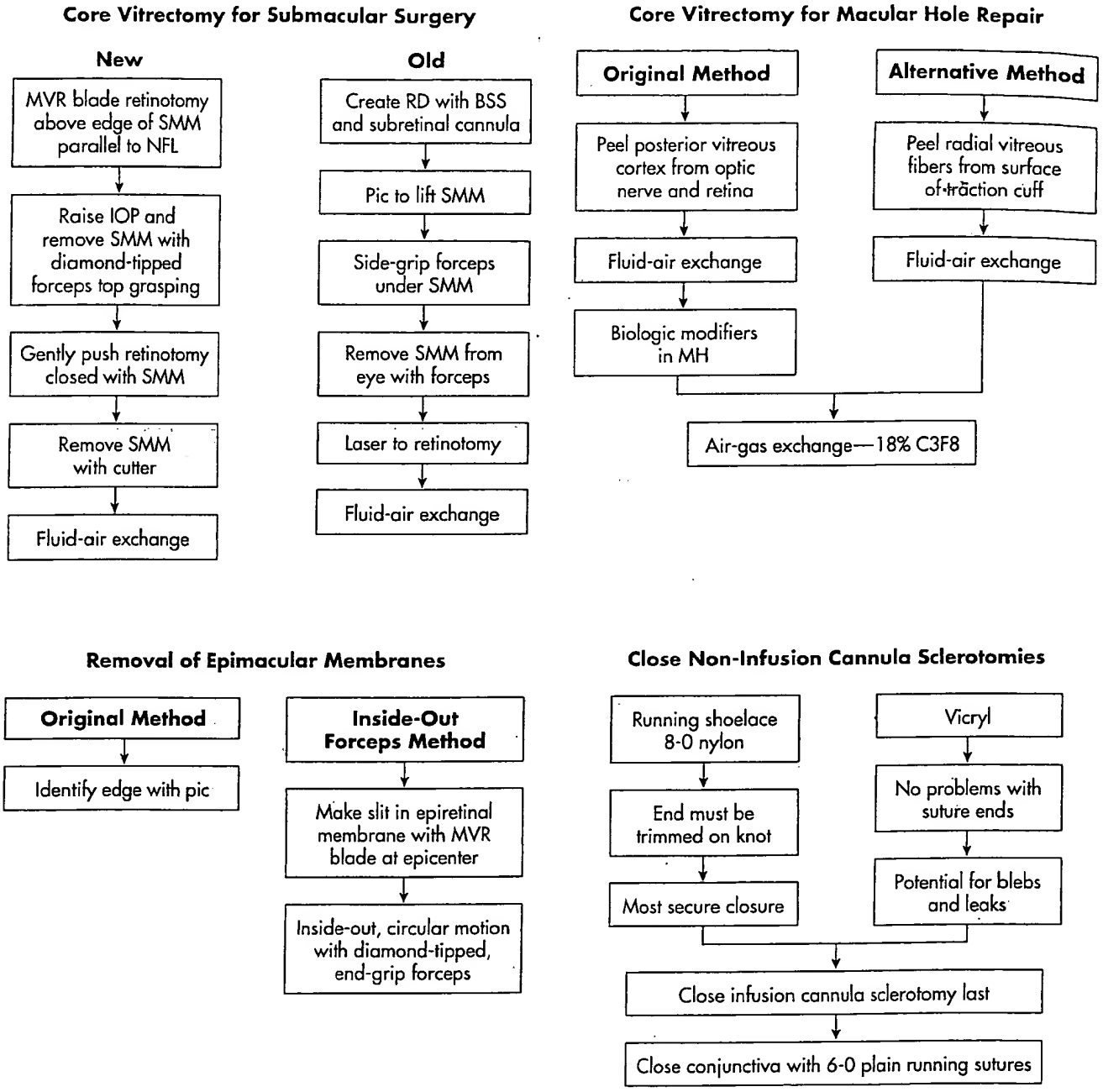

Fig. 127-45—cont'd Algorithms for common vitreoretinal disease states.